Purpose

The development of reliable public policies for guiding the growth of shopping centres and for evaluating retail proposals is one of most formidable and fundamental challenges confronting planning boards and municipalities today. Unsatisfactory municipal guidelines frustrate shopping centre developers and retailers alike.

The Ministry of Treasury, Economics and Intergovernmental Affairs is responsible for policy aspects of *The Planning Act* and, as such, has a vested interest in the kinds of tools and techniques that are being used by municipalities to formulate local planning policy.

This is the second publication prepared for the ministry to help public and private decision makers develop methods for guiding the planning and evaluation of major retail facilities.

The brisk demand for the earlier report, *Shopping Centre Decisions: Evaluation Guides* demonstrates the clear and present need for such guidance. *Shopping Centre Decisions,* first published in 1971 and since reprinted, illustrated the use of trade area analysis -- a step-by-step evaluation guide to decision making -- by detailing the results of two case studies. It pointed out advantages and limitations of this technique, and it urged that the potential of computer-based retail gravity models for use in Ontario be seriously explored.

This document examines two retail gravity models which are capable of handling and testing information to an extent not possible in trade area analysis. Again, two case studies are used to describe the application of these measurement tools.

Although the actual case studies were completed in 1972, considerable time and effort were spent on the preparation of the final manuscript to achieve clarity when discussing a very complicated subject. Meanwhile, however, there has been a free and useful exchange of the findings with several municipalities including the regional municipalities of Niagara and Waterloo, Oxford County and the cities of Kingston and London.

Now that the report is available, it is hoped that any future applications of similar evaluations will also be published as this will contribute greatly to the body of knowledge of these models and advance their usefulness to the public and private sectors. Acknowledgement of the use of this publication as a source document would be appreciated.

Both publications, *Shopping Centre Decisions* and *Planning Applications of Retail Models*, are the work of Robert W. McCabe, CD, BA, M Com, M Sc(Pl), MCIP. Mr. McCabe is a professional planner with many years of experience as a consultant, university lecturer, municipal employee and researcher, with special emphasis on retail location.

His task in preparing this document was made doubly difficult as he addresses two audiences -- those with experience in applying computer models and those without.

Mr. McCabe was assisted by C. A. Rabenda, BA, M Sc(Pl), and G. W. Wright, BA, M Sc(Pl), who were employed by the ministry and, at the time, were graduate students at the University of Toronto's Department of Urban and Regional Planning.

Acknowledgement is gratefully made of the cooperation of the many municipal people who helped in the preparation of material.

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1 Introduction: Bases, Approaches and Conclusion

The primary purpose of this study has been to explore the potential of gravity type models to assess the impact of new or expanded suburban shopping centres on the existing retail commercial facilities of a municipality. The study is a sequel to an earlier study published in 1971 entitled *Shopping Centre Decisions: Evaluation Guides* (McCabe 1971).

The previous study dwelt at length on the elements of risk inherent in shopping centre decisions and the adequacy of trade area analysis to answer the questions that decision makers must resolve to their satisfaction.

This study has been aimed at amplifying what is known about retail models and their ability to answer these and other related questions with equal or even greater reliability than current methods allow.

Retail Models and Shopping Centre Decisions

The potential usefulness of retail models for urban and regional planners and municipal decision makers rests on the claim that models can be helpful in providing answers to such basic planning questions as: How much retail space is required? Where should it be located? When will it be needed?

In more detail, retail models attempt to answer the following questions about shopping centre decisions:

1. What potential is there for existing or new shopping centres

in the area? How many centres and what size of centre can be supported? Which locations are best? When will new centres be required or when should existing centres be expanded?

2. How much in annual sales will be gained or lost by each centre when a new centre is introduced or an existing centre expanded?

3. Which pattern of centre sizes and locations offers the greatest potential or has the least adverse effects? Which pattern is most likely to maximize overall customer shopping satisfaction? Which best provides comparable levels of service to all residents in the area?

4. What are the consequences of alterations in the assumptions made about future travel times and distances, levels of per capita income, population growth rates, distributions and densities, and how might each affect retail location and shopping demand?

5. How similiar is the set of future centres to the set that might result from normal market processes? How "efficient" is the planned system of centres likely to be in producing reasonable productivity for the retailer measured in terms of centre size and sales per square foot, and how effective is the system likely to be in minimizing average trip lengths for the shopping public?

6. What levels of consumer flow are most likely from each residential area or neighbourhood to downtown and suburban shopping centres? What levels of sales are generated at each centre? How closely do these approximate existing conditions?

Like any method which attempts to evaluate what is likely to happen in the future under varying circumstances, retail models have their limitations. In the case of trade area analysis, which appears to be the only currently available alternative to retail models, the principal limitations are:

1. the high cost in time and money needed to test even a limited number of alternative arrangements under a restricted variety of assumptions about the future,

2. the lack of precision concerning the uncertainties involved in the use of estimates, and

3. the large number of factors that have to be kept straight in an

analyst's mind while he is doing his step-by-step calculations.

Retail models appear to overcome these problems by 1) allowing for the evaluation of an almost unlimited number of possibilities at low cost, 2) by delimiting precisely the effects of weak estimates or poor judgement, and 3) by making use of the ability of the model to keep large numbers of factors in focus while the necessary calculations are being made.

Retail Models and Public Policy

Retail modelling also appears to be the best means currently available by which municipal, regional and provincial governments can arrive at answers to policy questions crucial to their ability to plan for orderly growth and development.

Official plans in Ontario must by their nature incorporate provisions to ensure that residents will continue to enjoy the benefits of reasonably located shopping facilities.

Retailers too must be assured of a consistent set of policies within which they can plan the best means of serving their customers.

Failure to face these important policy issues invites the possibility of less than satisfactory conditions for shopping centres' consumers, retailers and property owners, and creates serious problems for elected representatives and their officials.

Among the major policy questions that retail gravity models can help answer are:

1. What are the probable consequences of a lack of policies or of a continuation of current policies and practices on the location of retail facilities?
2. Are policies on retailing consistent with other policies concerned with population distribution, densities, and the provision of transportation and piped services?
3. To what degree do existing retail facilities adequately serve existing populations and what will be the effect of trends to new forms of retailing?
4. At what scale do retail facilities cease to be of purely municipal concern and become a matter of regional interest?

5. To what degree does a proposed shopping centre, or several proposed centres, match the future desirable state of affairs envisaged by the official plan?

6. How much flexibility in defining exact retail locations can safely be built into a plan for the future?

Pressures for new and better located retail facilities will no doubt continue to force elected bodies at municipal, regional and provincial levels to seek ways of answering these and other policy questions.

APPROACH AND OUTLINE

The approach adopted for the evaluation of retail models is based on the same assumption that was made in *Shopping Centre Decisions: Evaluation Guides*.

Decision making is a matter of selecting a solution to a problem from among a number of perceived alternatives. The adopted solution is hopefully one that involves the minimum risk for the decision taker.

The planning process is designed to help the decision taker -- entrepreneur or politician -- make sure that risks are minimized by removing as far as possible uncertainties about the future.

This study has revolved around the ability of retail models to reduce uncertainty and to evaluate a wide range of possible alternatives under varying assumptions about the future in a realistic and pragmatic manner.

Chapter 2 reviews the development of retail models of the gravity type and describes in some detail the two models selected for intensive study. Understanding these models and how they operate should help the reader comprehend the results of the analyses contained in later chapters.

Some time is spent considering the conceptual, operational and informational bases of the two models so that a detailed comparison may be made between the legitimacy of retail models and of the only other means of evaluation, trade area analysis.

It has been assumed that readers are familiar with the way in which provision for orderly growth and development is achieved

under *The Planning Act* in Ontario and the role that has been played by market studies in the past.

Chapter 3 presents two case-study applications in Ontario employing the two models selected for examination.

Concern over the growing number of applications being received by local municipalities for permission to construct suburban shopping facilities appears to be most critical in urban centres with populations from 25,000 to 150,000.

Studies of the changing structure of retailing in North America indicate that the prime tenants in the larger shopping centres are currently moving into smaller communities in a major building expansion. Both case-study municipalities typify this situation.

Large centres on the other hand generally have access to the research and informational resources needed to carry out major retail studies. At the same time the addition of another centre in a large metropolitan region is less likely to have the critical impact of a large suburban shopping facility in a smaller community.

Finally, the complexities of retailing in very large centres such as Metropolitan Toronto might obscure the fundamental lessons to be learned about retail models.

A testing procedure is developed here for answering the questions posed in *Chapter 1*. Conclusions are reached by comparing the two versions of the retail model tested and the results achieved in each of the two case-study municipalities.

Chapter 4 contains a general review and evaluation of the results of the study. Special attention is given to aspects of retail modelling that require particular care by those who provide the information on which the models operate. The basic information used in retail models is shown to be largely identical with that required for trade area analysis.

A *Technical Appendix* has been prepared as a companion piece to the report. It sets out the operating instructions for the two computer models employed in the study in enough detail to permit their subsequent application at a municipal or regional government level by planning staffs or consultants.

Since computer language and technology mean little to the layman,

the appendix attempts to explain in non-technical language the procedures used in the two programs -- particularly for those who must place high reliance on the results of computer models.

Each of the two programs is presented separately. The information that is entered into the models (the input variables) is described and the information in the printed results is listed in detail (the output variables).

Program listings, explanations of the exact nature of each step and a flow diagram are provided for both programs. Additional options that the user may wish to use under certain circumstances are also explained and the necessary modifications in control cards or program decks specified.

The *Annotated Selected Bibliography* contains those publications on retail models -- many of them technical -- that users would likely want to become familiar with before attempting to apply either of the retail models or to interpret the results.

The *General Bibliography* lists all books, journal articles and government documents that were consulted or referenced during the study.

SOME GENERAL CONCLUSIONS

The application of retail modelling in the two case-study municipalities appears to have substantiated the powerful analytical advantages claimed for the models tested.

This was particularly true when they were employed in conjunction with conventional step-by-step trade area analysis. In both instances and for both models a close replication of existing retail shopping patterns was achieved. The dependability of short-term forecasts made by the models was amply demonstrated.

The models provided reliable and usable answers to the planning questions that were posed at the outset of the study and to the policy questions.

Differences were found, however, in the degree of reliability and the ease of operation of the models employed.

The Huff model proved to be easier to put into operation but less satisfactory in achieving an immediate close replication of

actual conditions.

The Cullen model proved to be superior in the manner in which the results are presented, in the reliability of its forecasts, and in the ease with which a close approximation of observed results is obtained.

Extensive applications of the models in as many operational situations as possible would now seem appropriate. It is important, however, that the results of all applications be published as a matter of course so that all those interested in the development of public policy may benefit. This is the only way expertise can be developed and the benefits of more widespread use realized. A number of these studies have already been made and more are underway at the time of writing.

More detailed conclusions will be found at the end of each chapter.

EMERGING ISSUES

Discussions with planning agencies and others about the nature of the studies undertaken brought out some further problems requiring attention:

1. Where regional governments exist, studies need to be undertaken at a regional scale even though a proposed centre may be located in a single constituent municipality.
2. Where regional governments do not exist, some co-operative means must be found to allow broader analysis of the implications of establishing suburban shopping centres in those municipalities that lie immediately outside the large urban centres.
3. An assessment of the implications of new forms of large-scale retailing that are just now emerging may be difficult to determine using only the currently available methods. Further refinements of trade area and retail modelling techniques may well be needed.

It would seem logical that the lead in developing new approaches to evaluating retail locations should come from the Ministry of Treasury, Economics and Intergovernmental Affairs, either

through its own staff or through arrangements with local or regional planning agencies.

2 Retail Modelling

Two formulations of the retail model have been investigated in the course of the research undertaken in this study.

The first is the Huff and Blue version of the Huff model which has been extensively revised in the Department of Urban and Regional Planning at the University of Toronto and, later, by the study researchers.

The original program is fully described in *A Programmed Solution to Estimating Retail Sales Potentials* (Huff and Blue 1964). The revisions were introduced to improve the tables produced by the model and make them more useful for planners and comparable to those produced by the second model.

The second formulation is the Cullen version of the Wilsonian entropic model (Cullen 1969) also extensively revised at the University of Toronto by the study researchers. A comprehensive understanding of this model requires a reading of the papers by Hayes (1968), Wilson (1970b), Batty (1972a) and Cullen (1969).

This chapter is written for those who want to gain a general understanding of the development and use of the two retail models used here without having to read all the relevant technical journals.

Previous approaches to an understanding of the distribution of shopping facilities and consumer shopping habits are reviewed, and the various models that have been developed are described. A comparison is made between the principal characteristics of the two versions tested.

This rather detailed description of the two models is

considered a necessary preliminary to appreciating the analysis reported in the case study chapter.

DESCRIPTIONS OF RETAIL SHOPPING ACTIVITIES

Early Gravity Models

Early investigations of the market area concept, relating the purpose, frequency and length of shopping trips to a hierarchy of centres, closely paralleled a set of empirical studies on spatial interaction. The underlying theme was that a definable relationship exists between the size of a city and the distance from which shoppers are attracted.

The gravity concept of human interaction postulates that there is an attracting force between two areas of human activity. This force is created by the mass of the two populations and by a friction against interaction that is exerted by the intervening space over which the interaction must take place. Interaction between two centres is seen as varying as some function of population concentration and the distance between them.

It was not until W. J. Reilly postulated his "Law of Retail Gravitation" in 1929 that the analogy with Newton's Law of Gravitational Force was specifically applied in marketing (Reilly 1929). Reilly first formulated his gravity concept to describe the attraction that two adjacent cities exerted on intervening small communities for the purchase of fashion goods. Reilly's Law states that:

> Two centres attract trade from intermediate places approximately in direct proportion to the size of the centres and in inverse proportion to the square of the distance from these two centres to the intermediate place.

In notational form the relationship is:

$$\frac{T_a}{T_b} = \left(\frac{P_a}{P_b}\right)\left(\frac{D_b}{D_a}\right)^2$$

where T_a and T_b represent the fashion goods trade drawn to two cities A and B from the intermediate place, D_a and D_b the distances from the intermediate place to A and B, and P_a and P_b the populations of the two cities.

Over the next decade the model was revised and broadened in its applicability. A break point was postulated between the trade areas of the two cities. This was the point at which customers were indifferent as to the city they shopped in. The formula was consequently modified to read

$$D_b = \frac{D_{ab}}{1 + \sqrt{\frac{P_a}{P_b}}}$$

where D_b denotes the distance from city B to the line of equal attraction, D_{ab} the distance between the two cities, and P_a and P_b the populations of the two cities (Fig. 2-1).

This formulation, like most of the early quantitative approaches to marketing problems, was only one of several attempts at deriving exponents or indices to explain a variety of distance-related phenomena.

The power function of 2, a squaring of the inverse distance, was arrived at by Reilly from field observations. The observed values, which fell between 1.5 and 2.75, were simple averages. Reilly made 255 field measurements in all and found that some exponents ranged from 0 to as high as 12.5. It has been claimed that for this reason alone Reilly's Law had a weak empirical basis -- an unvalidated hypothesis arrived at intuitively through an analogy with pure physics.

Marketing Analysis

Although Christaller is credited with hypothesizing Central Place Theory in 1933, formalizing the concept of a hierarchy of centres, the discipline of marketing had developed techniques for describing market activities much earlier.

Theories of retail location evolved based on estimates of trade areas for goods of different categories. The concept of convenience

REILLY'S BREAK POINT ANALYSIS

Determining the Breaking Point

The following formula is derived from Reilly's Law of Retail Gravitation. It has been used for determining the boundaries of a trade area, the 50 percent breaking point -- the point at which a town secures one-half of its trade.

At the breaking point two cities attract retail trade "approximately in direct proportion to the population of the two cities and in inverse proportion to the square of the distance from these two cities to the intermediate town".

A - Larger town
B - Smaller town

$$\text{Breaking Point, Miles from B} = \frac{\text{Miles between A and B}}{1 + \sqrt{\dfrac{\text{Population of A}}{\text{Population of B}}}}$$

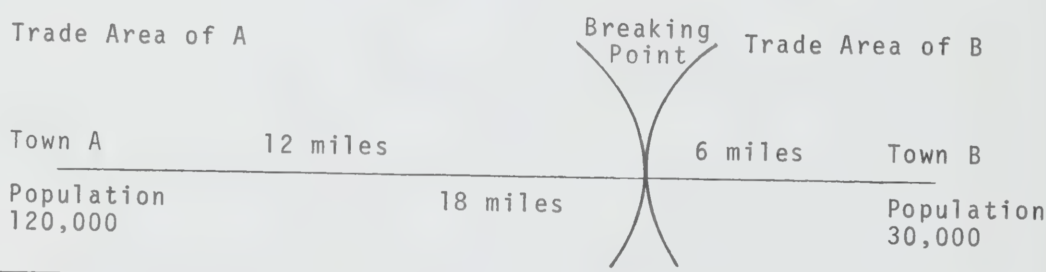


Fig. 2-1: Reilly's Break Point Analysis

Converse, Paul D. and Heugy, Harvey W., *Elements of Marketing*, 2nd Ed., New York, Prentice-Hall Inc., 1940, pp 641-2.

STEP-BY-STEP APPROACH TO TRADE AREA ANALYSIS

STEP I	Establish a tentative trade area for the centre
STEP II	Determine the initial desirable size and nature of the contemplated centre to assess its possible power of attraction
STEP III	Estimate the total potential purchasing power of the residents of the delineated trade area for the goods and services represented in the centre
STEP IV	Analyse the competing centres in the trade area and their relative attractiveness in relation to the proposed centre
STEP V	Survey consumer shopping habits in the trade area and determine the characteristics and attitudes of the shoppers, centre patronage, etc.
STEP VI	Estimate the share of the potential consumer expenditure in retail goods and services which will likely be attracted to the centre and translate this into retail floor space requirements by type of goods
STEP VII	Evaluate the findings of the trade area and market analyses in relation to the initial size and floor space allocation in the contemplated centre and adjust as necessary

Fig. 2-2: Step-By-Step Approach to Trade Area Analysis

McCabe, Robert W. *Shopping Centre Decisions: Evaluation Guides*, Toronto, Province of Ontario, Ministry of Treasury, Economics and Intergovernmental Affairs, 1971.

buying and comparison shopping as delineators of market areas and centre sizes existed in marketing literature prior to 1920 (Copeland 1922).

Marketing studies first concentrated on problems dealing with individual shops or classes of goods and their market areas. Advances in marketing techniques continued to be made and soon whole centres were being analysed instead of just individual outlets.

Later marketing studies of this nature came to be known as Trade Area Analysis or the Step-by-Step approach. The methods currently employed have remained substantially unchanged from the form it had developed by the 1930s.

Trade area analysis is discussed at length in *Shopping Centre Decisions: Evaluation Guides* (Fig. 2-2). Until very recently this method of analysis dominated studies of urban and regional markets.

The assumptions underlying trade area analysis are not dissimilar to those of Central Place Theory and early gravity formulations:

1. Primary and secondary trade areas are delineated and proportions of the consumer expenditures in each allocated to individual shopping centres. Relatively exclusive trade areas are assumed approximating a closed system.
2. The analysis is centre oriented.
3. A hierarchy of centres is postulated based on the types of goods carried.
4. The closest centre appears to be the most attractive.
5. The size of the trade area varies with the size of the centre.
6. Centres are evaluated one at a time. The evaluation of alternatives is time consuming and involves many value judgements on the part of the analyst based on his experience and the proprietary information held.

Trade area analysis has focused almost exclusively on the concept of retail trading areas like other early retail shopping studies. It appears to have been satisfactory in fulfilling the intended purpose of evaluating the retail potential of a single site. Theoretical and practical limitations appear when it is used for other purposes.

A Probabilistic Approach to Retail Modelling

It is only recently that tentative attempts have been made to develop a body of theory that links retail location studies to the major advances that have been made in marketing in the study of consumer behaviour. Early methods did not reveal why observed regularities in shopping patterns occurred nor were the hypothesized levels of activity based upon an accepted theory of how consumer shopping choices are actually made (Luce 1959).

Empirical studies in urbanized areas using customer shopping surveys indicate that consumers do not appear to discriminate among choices perfectly. For example, consumers do not appear to select one alternative consistently. The lack of consistency in choice becomes especially apparent where there are a large number of shopping centres of various sizes within a reasonable distance. As a result, distance in urban areas appears to provide significantly less protection from competition. A shopping centre is seldom able to dominate an exclusive trade area.

Trade areas also overlap because consumers find it pointless to continually discriminate among centres when the perceived differences between them are small.

A consumer may be uncertain as to the ability of each shopping centre to fulfill her various shopping trip expectations. She may visit one or all of them at some time or another in an information-seeking process.

But the next time she is confronted with the same choices in selecting a shopping centre, she will probably tend to choose among them in some more consistent manner.

This observation of shopping behaviour, especially in a highly urbanized area, differs in its point of emphasis from the traditional trade area analysis approach which begins by examining the site of the shopping centre. One of the strongest features of retail model formulations is that they do take this characteristic of consumer behaviour into account explicitly.

This new approach to the problem of dealing with trade areas was outlined in the early 1960s by D. L. Huff (Huff 1963). The apparent strength of Huff's probabilistic view of human choice behaviour over previous methods and the power of this version of

the retail model encouraged widespread research into retail models in the U.K., Scandinavia and elsewhere (Rhodes and Whittaker 1967; Agergard 1969).

Huff suggested that the areas of competition between shopping centres continually overlap. Consequently, shopping activities appear to be apportioned among the accessible centres in a probabilistic manner.

If the apportionment is probabilistic, the total of all shopping probabilities must be unity. If there are four centres, for example, and the probability of consumers in a given location of shopping at centre A is 0.5, at centre B 0.3, at centre C 0.05 and at centre D 0.15, the sum of the probabilities will equal 1.00 as required by the theory of probability.

DESCRIPTIVE AND NOTATIONAL FORMS OF RETAIL MODELS

Description of the retail models is split at this point into two sections. Part A is purely descriptive and is provided for those who are not fully familiar with mathematical notation. Part B is in notational form for those who find that means of expression simpler to follow.

A. The Descriptive Model

(1) The probability that a customer who lives in a certain area of a community, defined as a population zone, will be attracted to any one retail centre is the ratio of the attractiveness of the centre to the distance from the zone centroid to the centre raised to a power, defined as lambda (λ), divided by the sum of all the similar ratios for all the zones and all the centres.

(2) The sum of all these probabilities must sum to unity, that is, 1.0.

B. The Model in Notational Form

(1) The probability that a consumer from zone i will be attracted to retail centre j can be expressed as:

$$P_{ij} = \frac{\dfrac{A_j}{d_{ij}^{\lambda}}}{\sum_{j=1}^{n} \dfrac{A_j}{d_{ij}^{\lambda}}} \qquad \text{(for any zone)} \qquad (1)$$

where

P_{ij} = the probability that consumers in zone i will be attracted to centre j;

A_j = the attractiveness of centre j;

d_{ij} = the distance from zone i to centre j;

λ = a parameter value which is to be estimated empirically to reflect the effect of travel distance, time or cost on shopping trips.

(2) Subject to

$$\sum_{j=1}^{n} P_{ij} = 1.0 \qquad \text{(for all zones)} \qquad (2)$$

A. The Descriptive Model

(3) The amount of retail sales that are available in any zone is the product of the number of people who reside in the zone and the average per capita expenditure on retail goods and services.

(4) The portion of the available retail expenditure from the zone that will be attracted to any given centre is the product of the total available expenditures and the probability that customers from that zone will be attracted to the given centre.

(5) The sum of the sales attracted by each centre from a zone will equal the total available retail expenditure in that zone since the total of all the probabilities must equal unity.

If the sales at each centre from each of the zones are summed, i.e., the sales at Centre A from Zone 1, plus the sales from Zone 2, plus the sales from Zone 3, etc., an estimate is obtained of the probable sales at that centre.

In the four-centre case mentioned earlier, if the total available retail expenditure is $100,000 -- the product of a per capita retail expenditure of $500 from 200 people -- sales at Centre A from that zone will be $50,000 ($100,000 x 0.5), at Centre B $30,000, at Centre C $5,000 and at Centre D $15,000.

B. The Model in Notational Form

(3) The total available retail expenditure from zone i can be expressed as:

$$E_i = B_i \cdot C_i \qquad (3)$$

where

E_i = retail expenditure in zone i

B_i = average annual retail expenditure per capita

C_i = the number of consumers in zone i

(4) The amount of business attracted to a centre j from zone i can be expressed as:

$$S_{ij} = E_i \cdot P_{ij} \quad \text{(for any centre)} \qquad (4)$$

where

S_{ij} = the retail sales attracted to centre j from zone i

(5) Substituting, it can be seen that

$$S_{ij} = E_i \cdot \frac{\dfrac{A_j}{d_{ij}^{\lambda}}}{\sum\limits_{j=1}^{n} \dfrac{A_j}{d_{ij}^{\lambda}}} \qquad (5)$$

A. The Descriptive Model

(6) If the sales of each centre are summed, that is, the sales at Centre A plus the sales at Centre B plus the sales at Centre C and so forth, the total of all the retail sales by all the centres is produced.

If the total available retail expenditures for each zone are summed -- the expenditures in Zone 1 plus the expenditures in Zone 2, etc. -- the total of all retail expenditures is obtained.

By definition the total of all retail expenditures by customers must equal the total of all retail sales made by stores.

It is obvious that some people may spend some of their money for retail goods outside the community altogether. An adjustment must be made for this outflow. It is equally obvious that some people making purchases in the stores in the community may not be residents. An adjustment must be made for this inflow as well.

B. The Model in Notational Form

(6) Subject to the constraint that

$$\sum_{j=1}^{n} S_{ij} = \sum_{i=1}^{n} E_i \qquad \text{(for all centres)} \qquad (6)$$

where

S_{ij} = the sales attracted to centre j from zone i

E_i = the expenditures made in zone i

A. The Descriptive Model

(7) Having calculated the estimated share of sales coming from each zone and arriving at an estimate of the sales at each centre, it is possible to compare this estimate with the actual sales at each centre. Actual sales are not normally available from centre operators, but methods have been devised for estimating these independently of the steps followed previously. If the calculated sales and the estimated sales do not match within reasonable limits it is assumed that the difference is accounted for by the friction of distance and that adjustment for this factor can now enter the calculations by varying the value of lambda (λ). By the use of search techniques it is possible to arrive quickly and simply at a value for lambda (λ) such that the calculated and actual sales are in close approximation. The model is then said to be calibrated.

B. The Model in Notational Form

(7) In a hypothetical case, a summary of the site information produced by the model might show the following results of calibration at various values of lambda (λ) in table form.

Lambda (λ) = 0.8 Year = 1966

Centre	Calculated Sales ($ million)	Actual Sales ($ million)	Difference Squared (x 10^{11})
1	20.2	20.6	1.6
2	7.8	7.8	-
3	54.9	54.8	0.1
4	9.2	8.8	1.6
5	5.8	5.9	0.1
Totals	97.9	97.9	3.4

Lambda (λ) = 0.85 Year = 1966

Centre	Calculated Sales ($ million)	Actual Sales ($ million)	Difference Squared (x 10^{11})
1	20.1	20.6	2.5
2	7.9	7.8	0.1
3	55.0	54.8	0.4
4	9.3	8.8	2.5
5	5.6	5.9	0.9
Totals	97.9	97.9	6.4

In this case the first table appears to achieve a closer fit between calculated and actual sales and the calculated value of λ = 0.8 is more probable.

<u>A. The Descriptive Model</u>

(8) To test the validity of the calibration, the practice is to make a forecast or a backcast using the model as it calibrated to see how closely the forecast comes to conditions that are known to exist at the forecast or backcast date. For example, if the model is calibrated on 1966 information, an attempt can be made to predict what the model says the 1971 situation would be, given more population, higher incomes, new or expanded centres, etc. The forecast for 1971 is then compared with known 1971 information and the predictive accuracy of the model judged. If the predictions are faulty, a re-examination can be made of all the factors that have entered into the model for each year to see if there are any errors or bad assumptions. Generally, the predictive power of the model is found to be very good once inadvertent aberrations are removed.

B. The Model in Notational Form

(8) In a hypothetical case a comparison of the estimates for 1971, with lambda (λ) set at the 1966 best value of lambda (λ) = 0.8, might show something like:

Lambda (λ) = 0.8 Year = 1971

Centre	Estimated Sales	Actual Sales	Difference Squared (x 10^{11})
1	22.4	22.9	2.5
2	9.5	9.7	0.4
3	57.0	56.4	3.6
4	10.1	9.8	0.9
5	5.9	6.2	0.9
6	8.2	8.1	0.1
Totals	113.1	113.1	8.4

A. The Descriptive Model

(9) A refinement to the Huff formulation, known as the Lakshmanan and Hansen model, was devised by Lakshmanan (Lakshmanan and Hansen 1965). Further extensions have been made by a variety of researchers. Lakshmanan made the adjustment to raise both the attractiveness factor and the distance factors to a power. In this case these are known as the alpha (α) and beta (β) values. The model is calibrated as before but both α and β values may be adjusted to bring the calculated and actual sales into line. (β is identical to λ in the earlier model.)

B. The Model in Notational Form

(9) Where both A_j and d_{ij} are given parameter values that enter into the calibration, the Lakshmanan and Hansen formulation reads:

$$S_{ij} = E_j \cdot \frac{\dfrac{A_j{}^{\alpha}}{d_{ij}{}^{\beta}}}{\sum_{j=1}^{n} \dfrac{A_j{}^{\alpha}}{d_{ij}{}^{\beta}}} \qquad (7)$$

subject to the constraint that

$$\sum_{j=1}^{n} S_{ij} = \sum_{j=1}^{n} E_i \qquad \text{(for all centres)} \qquad (8)$$

where

α and β are two parameters, one of which (α) reflects the variations in attractiveness caused by assortments, differences in retail shops, etc., and the other (β) is identical with (λ) in earlier versions of the model.

A. The Descriptive Model

(10) Wilson has suggested that the retail version of the general gravity model may be more rigorously formulated through the processes of statistical mechanics. In this form of the model, an exponential function is used in place of the power function of α and β employed by Huff and Lakshmanan. The version of the gravity model used during this current study was developed by Cullen at University College, London in 1969 and employs Wilsons' arguments. Newer developments in the retail modelling field typically rely on similar, more rigorous formulations. It was thought best, therefore, to adopt the Cullen version from the start. In effect, the Wilsonian approach overcomes any of the criticisms of the retail model as having a weak empirical basis.

Earlier versions were founded on a tenuous analogy between retail shopping patterns and Newtonian physics. The Wilsonian version is derived on a strict empirical basis in a rigorous mathematical manner.

B. The Model in Notational Form

(10) The Cullen version of the Wilsonian entropic model takes the form:

$$S_{ij} = \frac{E_i \cdot e^{\alpha w_j - \lambda d_{ij}}}{\sum_{j=1}^{n} e^{\alpha w_j - \lambda d_{ij}}} \tag{9}$$

where

S_{ij} = sales attractiveness of zone i to centre j

E_i = the household or per capita retail expenditure in zone i

w_j = an index measure of attractiveness of centre j

d_{ij} = some measure of cost of travelling from zone i to centre j

α = a shopping centre attractiveness factor

λ = a travel cost parameter

THE SELECTION OF VARIABLES

The ability of a shopping centre to fulfill the shopping demands of a consumer is obviously determined by a host of factors. Among those substantiated are newness, the presence of an enclosed mall, air-conditioning, the reputation of the retailers represented, the size, choice and price of goods, ease of parking, distance from home and advertising effectiveness. Attempts to weigh the individual importance of such factors have met with limited success.

Recent research has confirmed that only a few of the variables are important enough to be included in workable models that ensure valid and reliable predictions. In food supermarkets, for example, price, location, quality and service appear to dominate all other marketing factors (Tigert 1971).

In the retail models developed to date, two principal variables are assumed to exert enough influence that collectively they can be safely used as proxies for all the other variables in making predictions. These two variables are:

(a) the number of items that are carried by a shopping centre, and

(b) the travel time involved in getting there.

Items Carried

A consumer cannot always be positive in advance that a particular shopping centre will fulfill the purpose of the trip being planned. The shopping centre may or may not have the particular item or brand of item that a consumer wishes to purchase. However, a customer usually has some prior knowledge that a specific shopping centre will satisfy her needs and presumably this is based on the number of items she feels are carried by the centre. So the greater the number of items carried the greater will be the expectation that a shopping trip will be successful.

Consumers, therefore, seem to prefer larger centres and to show a willingness to travel further to reach them. The degree of uncertainty in consumer shopping decisions appears to diminish as the size of the shopping centre increases, reflecting the assumed increase in the number of items available.

Distance

The desirability of a shopping centre is also assumed to be influenced significantly by the effort and expense involved in getting there. The consumer bears the burden of movement to the centre in terms of the required preparation time, monetary costs and travel time invested. Consequently, there would appear to be good reason to suggest that a consumer attempts to minimize these costs in some way.

However, there is strong evidence that the minimum cost choice is not consistently selected to the point where shopping is done only at the nearest centre. The desire to minimize the costs of movement reflects the notion of opportunity costs. The consumer is assumed to have only so much time. If the time is devoted to more than one activity at the expense of others, the costs of foregone opportunities rise to act as a check against further time losses. Therefore, the value of a shopping centre to a consumer seems to be in some way inversely related to the effort and expense involved in getting to it.

In many instances, especially for intra-urban shopping trips, there are only minor differences in distance to each of the centres that appear to the consumer to be accessible. In these circumstances, the effect of distance on the selection of any one centre over the others would be minor. Current retail model formulations realistically reflect this thinking.

Moreover, willingness to travel is not constant for all items. The more frequently purchased convenience goods do not command as great a willingness to travel on the part of the consumer as do the less frequently purchased, higher cost shopping goods.

Different types of merchandise appear to require different amounts of consumer searching. Variations in the effect of travel time for different kinds of shopping trips are reflected in very recent retail models that deal with each level of centre hierarchically. Models of this type appeared only after the current research was completed and have yet to be released for evaluation and testing.

Parameters

The majority of early efforts by Reilly and his followers to delineate trade areas had assumed that a power function of 2 -- the squaring of the distance -- was inherently correct and that this value would apply equally to intra-urban and inter-urban shopping trips.

This assumption became the target for much criticism when studies revealed that parameter values appeared to fluctuate depending on the type of trip being analyzed as well as the geographical area in which the study was made.

Parameters are used in most models to equate predicted to observed results. A parameter is a weight or effect not directly measurable which may or may not be estimated independently of the model. Distance and attractiveness parameters are examples in the two models used in this study.

Where parameter values cannot be estimated independently, they must be determined internally in the model by a calibration process. For example, where attractiveness is being measured according to some direct scale of shopping provision such as items carried, floorspace or sales, there is a case for introducing an exponent to allow for the extra attraction of choice.

In some instances it has been observed that two shops of a given type in one centre may be more than twice as attractive as a single shop of the same total size, presumably because of the cumulative attraction offered by the added choice in shopping. The exponent would take a value other than unity in this case.

Variations in parameter values may be assumed to allow for factors such as the added attractiveness of a large centre over and above its size to a smaller centre because of its wider choice of goods, ease of comparison, and other intangible factors not incorporated in the model.

Examples of factors which are usually present in varying degrees for different size centres are:

1. an apparent increase in amenity as centre size increases,
2. the superior attractiveness of major "name" food and department stores usually found in a larger centre,

3. greater ranges, assortments, depth of stock, etc.

Where attraction measured in terms of size alone is being used as a proxy variable for a number of other attributes, the use of the attraction parameter reflects the accumulation of these unmeasured factors during the calibration process. But not all models incorporate this particular parameter.

A distance exponent is introduced in all model formulations to reflect the conclusions of earlier studies that different types of merchandise support differing amounts of consumer effort. The problems created when two-parameter versions of the model are employed are discussed later.

THE CHOICE BETWEEN MARKET STUDIES AND RETAIL MODELS

There are two approaches to the study of intra-urban or intra-regional retail systems of centres. One entails subjective judgements based on observations of similar conditions from which generalizations have been drawn, for example in the step-by-step method. The other makes use of empirically derived mathematical formulations, as do retail models.

Mathematical models which incorporate probability concepts have a number of important advantages over subjective methods of evaluation for the urban and regional planner.

1. The real world is represented in abstract and simplified terms.
2. The extensive analytical capabilities of the computer can be effectively used. Large scale quantification is essential when trying to estimate the effect of one or more changes on an area containing many centres. The problem that an analyst faces in trying to keep a multiplicity of interacting variables straight in his mind at one time is overcome. Flexibility is thereby enhanced and a large number of options can be tested.
3. The speed of computer applications produces instant feedback and provides a methodology that is relatively inexpensive and easy to use.
4. Acceptable solutions can be reached more quickly by allowing the model to eliminate those proposals that do not meet

predetermined criteria.

5. The large amounts of statistical data available for urban centres can be readily analyzed and speedily retrieved in readable form.

Like the step-by-step approach, the probability models described in this report are static in nature. They examine only successive states of temporary equilibrium over time. The intervening processes of change are not taken wholly into account.

NECESSARY ASSUMPTIONS IN OPERATING RETAIL MODELS

A simplified block diagram of the retail modelling process is reproduced from *Shopping Centre Decisions: Evaluation Guides.* (Fig. 2-3). Five general areas of interest underly the operation of retail models. These are the boundaries of the study area, the origins of shopper trips, measures of attractiveness and of distance, and locations of new centres.

Study Area

Unlike previous methods, probability models do not assume that a clearly delineated closed market area exists for any one centre or system of centres. The retail system for each centre may be considered to be open.

The resulting boundary is defined in such a way that total expenditure available to the centres in the system must equal the total sales that result.

In effect, a boundary is chosen such that the net boundary flow is negligible in comparison to the total trade in the study area. It is sited far enough from the centres under study to ensure that there is a negligible error in the calculations relating to these centres.

The boundary is also drawn to include the majority of the people who are likely to do their regular shopping at the centres under study.

There may still be a certain number of people living in areas outside the boundary who shop at the centres in question. An adjustment may be necessary to account for aberrations. If Total

SIMPLIFIED BLOCK DIAGRAM OF RETAIL GRAVITY MODEL

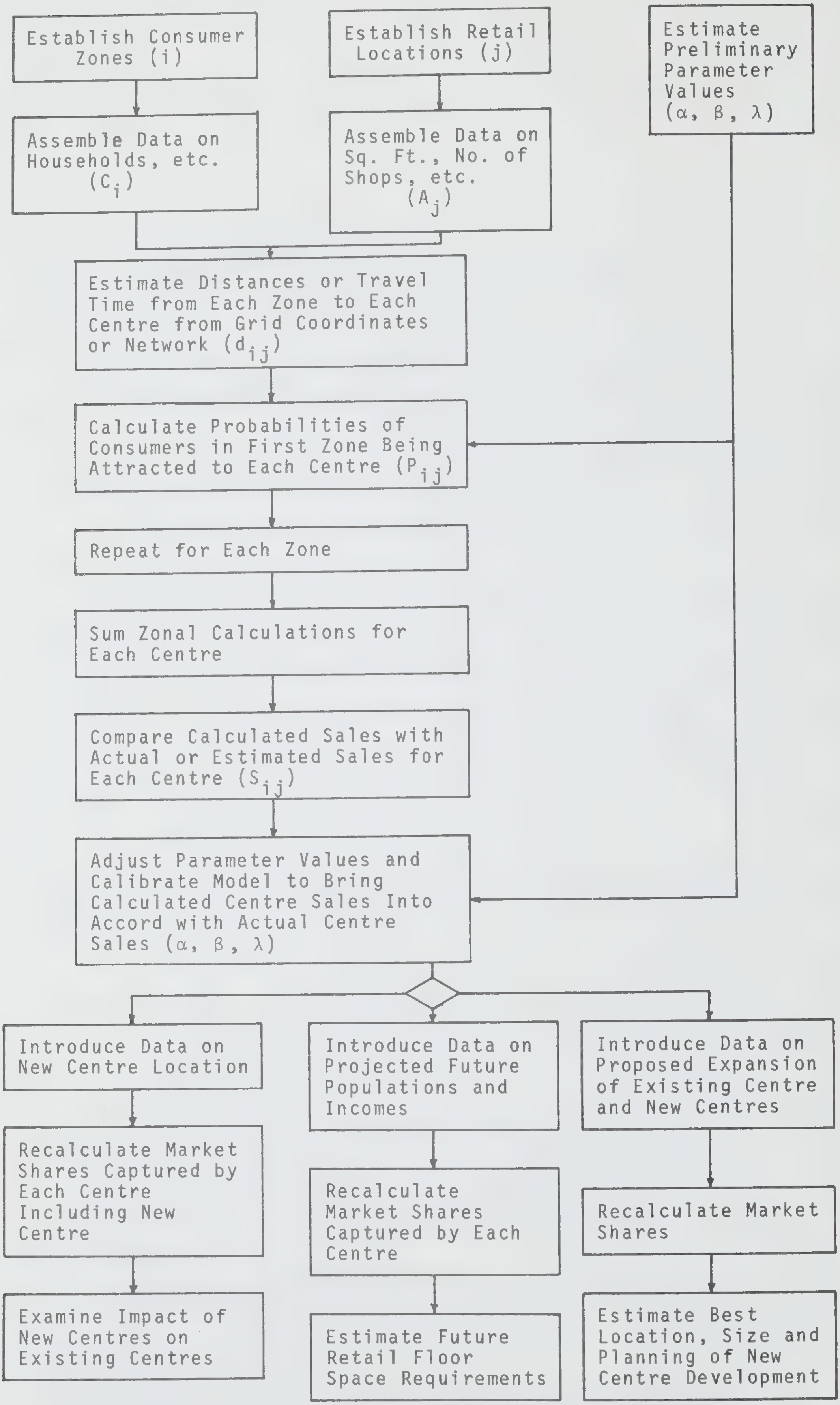


Fig. 2-3: Simplified Block Diagram of Retail Gravity Model

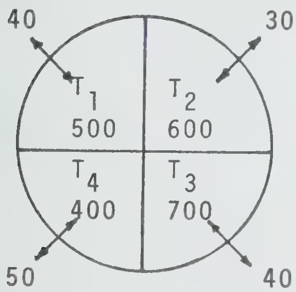
McCabe, Robert W. *Shopping Centre Decisions: Evaluation Guides*, Toronto, Province of Ontario, Ministry of Treasury, Economics and Intergovernmental Affairs, 1971.

DETERMINING THE SPATIAL LIMITS OF A STUDY AREA

1. <u>The "Closed" System</u>

   a) Flows to or from external areas subtracted from mass variables.

   b) External flows aggregated as a "dummy" variable.



$T_1' = 460$

$T_2' = 570$

$T_3' = 660$

$T_4' = 350$

$$T_{ij} = \sum_{i=1}^{n} Pi \cdot \frac{\dfrac{P_j}{d_{ij}{}^{\beta}}}{\sum\limits_{k=1}^{m} \dfrac{Pk}{d_{ik}{}^{\beta}}}$$

where k

$$= \frac{P_1}{d_{11}} + \frac{P_2}{d_{12}} + \frac{P_3}{d_{13}} + \frac{P_4}{d_{14}} + \frac{E}{d_{1e}}$$

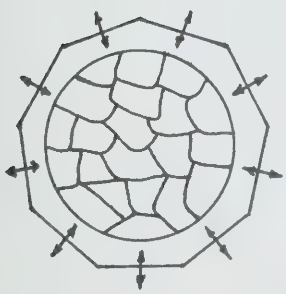
and E is external attractions

e is external distance.

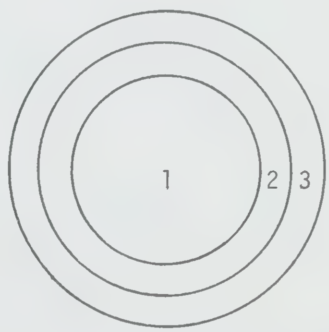
2. <u>The "Open" System</u>

   a) Flows to or from external areas are aggregated to larger zones.

   b) External flows are calibrated through a series of rings.



Further interactions across the external boundary should be compensated for.



1. Iterate for all internal areas.
2. Iterate for trips to areas in 1, 2, 3.
3. Iterate for subsequent trips to areas in 2, 3 and elsewhere if necessary.

Fig. 2-4: Determining the Spatial Limits of a Study Area.

Davies, R. L. and B. J. Styles (eds.). *Gravity Models in Town Planning*, Coventry, Lanchester College of Technology, 1969, p. 45.

Available Retail Expenditures do not equal Total Actual Sales for the centres under study, then:

(a) the study boundary is unrealistic and includes more people than those who do their regular shopping at the centres under study, or

(b) a nearby large centre outside the study boundary is capturing a significant proportion of the retail sales from centres within the study area, or

(c) there is a deficiency of shopping facilities in the study area and therefore a potential exists for a new centre or additions to established centres.

Arriving at a study area boundary is less likely to be a problem for a regional system of centres. The peripheral area is often devoid of competing centres. Problems do arise if an attempt is made to assess the potential of a number of centres that constitute only a portion of a metropolitan area.

In this case a closed system is preferable and estimates may be needed to delineate the effective distance people might be willing to travel to patronize the centres under study -- the centre study boundary.

Some account must then be taken of the centres existing outside the boundary to which a portion of the consumer spending within the centre study boundary might be attracted, especially from those consumers near the periphery.

A dummy variable may be introduced to represent external centres and an appropriate distance measure assigned to it. (Fig. 2-4)

Consumer Origins

The applications of the two retail models used in this study assume that the origin of all consumers is from their place of residence, that is, residential zones.

The models have been capable of accounting for shopping trips made from place of work since their inception. Thus major employment areas can be properly accounted for as sources of sales for nearby shopping centres provided suitable survey data on

expenditures at place of work is available.

The percentage of sales that come from the large number of office employees working in the central-city office buildings of major metropolitan areas like Toronto, Ottawa, and London provides a clear illustration of how significant this factor can be in some cases. Large decentralized industrial or office parks can have a similar effect on suburban shopping centre sales.

Adjustments in the average per capita retail expenditures in residential zones become necessary if place-of-work shopping is introduced.

Centre Attractiveness

Previous studies have shown that a variety of measures may be used as proxies for attractiveness. The number of items carried by the total complex was discussed earlier as a possible measure.

Other measures have been devised which have proved to be equally reliable and less laborious in their preparation. Floor space, annual sales, number of store types and number of employees are some of the alternative measures that have been applied.

Shopping centre sales volume is probably the most precise measure. Unfortunately, information on sales by shopping location is not always available because of disclosure rules. For this reason the selling area in square feet -- gross leasable area -- is used either directly as a proxy or as the basis for estimating annual sales.

Either option appears to be reasonably realistic for developing public policy because of the general consistency in sales and sales per square foot of gross leasable space in shopping centres.

Total annual sales estimates from retail footage appeared in most trade area analysis examined in 1972 to be based on a relatively constant ratio of about $60 per square foot for Department Store Type Merchandise (DSTM) floorspace and $120 to $160 for Food floorspace.

Separate estimates for DSTM and Food floorspace are usually preferable because of the significant difference in sales-per-square-foot ratios.

The limitations of these assumptions are fully recognized since it is known that sales-per-square-foot ratios can vary between centres and between the same stores in different centres. However, this is a problem that retail models share equally with trade area analysis.

As a consequence, retail models cannot be held inferior in this respect. In fact, the need to be explicit in the assumptions made about sales at each centre indicate that retail models are more open than trade area analysis with fewer hidden assumptions.

Floorspace figures expressed in square feet of gross leasable area are the most readily available measurement of attractiveness. There are no official published statistics on retail floorspace but this information can likely be obtained from planning offices.

In many instances it is necessary to do an independent study of existing floorspace. Great care must be exercised in the methods of measurement and recording to ensure that the results are accurate and categorized in such a way that they relate exactly to published sales-per-square-foot data.

Distance Measures

Distance may be measured in several ways. The simplest is straight-line distance. The most complex is probably an index of time/distance/cost for each of the available modes of transportation. Other simple measures may be expressed in terms of travel time or travel cost.

Straight-line distance takes no account of such matters as traffic congestion, the frequency and price of public transport, variation in car ownership, cost of parking, physical barriers and standard of roads. It seems clear that some combination of time-distance and travel cost provides a preferable measure.

In certain situations, however, very little in accuracy appears to be sacrificed in using straight-line distances. In other cases it seems to result in significant distortions.

Straight-line distance has the advantage that it can be computed internally by the computer using a grid reference system saving considerable time and expense. However, the use of straight-line distances in large metropolitan areas can usually be avoided

if good travel-time information at a fine scale of detail is available and if the time and cost involved in retrieval from traffic study data files is not exorbitant.

In smaller centres, where traffic data is less likely to be available, the use of straight-line distance presents more serious limitations because small centres often have a less homogeneous transportation system and a more diverse settlement pattern. In some circumstances it is possible to actually drive the distances to all centres from each population zone in the study area under varying traffic conditions and thus produce a valid set of travel-distance figures.

The two major assumptions about the effects of distance on shopping movements are that they are the same for all socio-economic groups within the study area and that the parameter value of the distance variable remains constant over limited time periods.

Future populations are viewed as reacting in the same way to the deterrence factor of travelling as in the base year, notwithstanding possible effects of changes in, say, disposable income, increased leisure, improved transportation facilities or altered marketing strategies. The effect of this assumption must be weighed against the observed dramatic change in consumer food shopping patterns that occurred in 1970 when the leading chain food supermarket went to discount pricing in Ontario (Tigert 1971).

New travel-time estimates may be used to reflect road or highway improvements but parameter values cannot be adjusted with any degree of assurance. Projections limited to five years into the future may partially offset this problem but short-term changes in consumer behaviour cannot be taken into account.

New Centre Locations

Retail models do not automatically select optimum location for new centres. Alternative sites or arrangements of sites may be evaluated against whatever criteria have been judged as desirable.

Possible shopping locations are first decided upon. Estimates of probable sales levels at the new centre and all the existing centres are then generated by the model. The consequences of other contemplated actions can be estimated by analyzing alternative

locations and by varying the size of proposed centres. The solution finally adopted will be optimal only for the range of alternatives tested.

Several types of analysis are possible. The analyst can examine the minimum size needed for a proposed centre, the possibility of adding more retail floorspace in any location up to a specified maximum, or the effect of alternative population densities around the centre. The analyst's imagination and the realities of the retail situation are the only limits on the analyses possible.

Both models offer considerable flexibility to the planner. The Huff version allows for the use of consumer survey data to calibrate the model where such data is available at a zonal level. It also allows for the evaluation of the profit potential at a site under incremental size levels up to a specified maximum. The Cullen version also has a number of options that can be selected -- a single-run projection, an equilibrium projection and a dynamic projection.

All procedures for both versions were tested during the course of the study. While no attempt is made here to discuss all the options and their applications, it was confirmed that they do operate as claimed. Nonetheless, further research in the use of the options in operational applications in Ontario would be helpful, and instructions for implementing the various options are included in the *Technical Appendix.* Further discussion of the options will be found in the Huff and Cullen references.

Retail modelling has qualities that appear to make it superior to other methods. There are, however, a few factors affecting locational choice that are not considered. These include site characteristics such as visibility, total road frontage, condition of road access, topography, drainage, amount of grading required, soil conditions, services available, cost of purchase, municipal building restrictions, and performance standards.

These factors are important to planners and retailers. But they are not critical since it can be assumed that the sites to be evaluated would be expected to meet these conditions in any case.

SOME GENERAL COMMENTS ON RETAIL MODELS

The principal criticism of retail models has centred around the impression that the retail gravity model is based on a weak analogy between aggregate consumer behaviour and Newtonian physics.

Early versions, like Reilly's Law of Retail Gravitation, were indeed dependent on the similarities between the attractiveness of mass in retailing and the deterrence of distance.

New strength and new direction has been given to retail modelling in the past two or three years by major conceptual and operational breakthroughs.

This is particularly true of the work of Wilson at the Centre for Environmental Studies in London and that of the scholars and practitioners working at the Planning Research Applications Group in Reading (Wilson 1969c and Wade 1973).

The Wilson derivation, while resembling in general form the older gravity models, overcomes any possible criticisms of the retail model as having weak empirical or conceptual bases. The Wilsonian entropic model used in these studies was rigorously derived through the process of statistical mechanics. It is based on the principles of entropy maximization which hypothesizes that the most likely state of any system can be approximated given sufficient knowledge about how the system behaves.

If all that is known about the system is reduced to a series of system equations, the most probable state of the system can be calculated. In the case of the macro-retail shopping system this has been accomplished and remarkable replication of observed shopping activities results.

An important feature of the Wilsonian version of the model is the use of an exponential form of the attractiveness and deterrence functions in place of the power functions employed by Huff and Lakshmanan.

The shape of the exponential curve of parameter values is somewhat less flat than that of the power curve. The calibration of actual to calculated results is therefore more easily obtained as the differences between solutions are more sharply defined along the curve of exponential values.

The effect of the exponential function is to decrease the number of longer trips hypothesized by the Huff version in favour of shorter trips, thus producing a distribution more nearly like that typically observed.

A criticism of the Cullen version is that, like the Lakshmanan version, it calibrates on two-parameter values. The technicalities of the propriety of the two-parameter version are the subject of much discussion in the journals (Batty and Saether 1972). Lakshmanan overcame the difficulty by setting the attractiveness parameter at 1.0 and calibrating only on the distance parameter. This simply produced a restatement of the Huff version.

A more serious problem is that of determining whether the calibrated parameter values provide a unique solution or whether other values may not provide an equally good fit of actual and calculated values of centre sales.

This problem has not yet been resolved. However, if due care is taken to ensure that the area of search for a good fit excludes the "bogus" calibration that is achieved when both values are set equal to zero, and that it includes values well beyond those typically found in studies conducted elsewhere, a set of values will emerge that appear to be optimal.

In this study, and in others conducted before and after, a best fit was found within narrow limits in each case that optimally related actual and calculated centre sales.

The most frequently asked question about retail models is why they fail to take into account all the factors that are assumed to affect centre sales. In fact, versions of the model have been formulated in which other measures of attractiveness in addition to size have been incorporated.

For example, it is known that the reputation of a particular retailer may have a beneficial effect on the sales in a centre if that particular retailer located in the centre. That retailer's drawing power relative to size is larger than that of other retailers.

The benefits of the selected retailer's presence presumably will be reflected in the operational efficiency of the centre and consequently in the level of sales per square foot derived from the

selling space. If these beneficial effects could be measured without violating the disclosure rules of Statistics Canada, great advances would be possible in retail modelling.

In these circumstances, given the mix of shops in a centre, the attractiveness parameter might be estimated independently of the model and a valid calibration achieved on the distance parameter alone. Other differentials in drawing power by class of retailer, by geographic areas, and by the socio-economic characteristics of customers can be envisaged.

This exact information is contained in the files of Statistics Canada and could be published subject to the normal disclosure rules. A shortage of government funds apparently prevents this being done.

Most other questions can be answered by stating that retail models use the same data sources as trade area analysis for sales, centre sizes, populations, incomes and retail expenditures for the past, present and future.

Both can encompass the results of consumer survey if necessary.

Shopping models, however, incorporate spatial relationships in a much more precise and rigorous manner and allow for the testing of a large number of alternatives which trade area analysis cannot do, except at prohibitive levels of expenditure of time and money.

Retail models are macro-level in nature. They do not attempt to predict the behaviour of individual consumers although there is little doubt that the understanding of observed shopping patterns would be enhanced by a clearer understanding of the shopping behaviour of individuals.

Such micro-level models are now being studied and much has been learned. Still, it is questionable, even if it could be explained today why two families of identical socio-economic and cultural backgrounds living side by side consistently shop in different shopping centres, whether any better prediction of consumer shopping behaviour at a macro-level could be achieved.

The real issue for urban and regional planners is not whether shopping models might be improved, but the degree to which planners themselves are attempting to apply what is already known when answering the complex questions with which they are faced.

At the macro level alone, a considerable amount of preparation is required before shopping models can be used in the decision-making process. One essential requirement is a body of reliable statistics, at a fine level of detail, on such fundamental matters as retail and service floorspace, population distribution, distance and income estimates, retail spending and sales.

Just as essential is a sound grasp of the nature of retailing as an urban activity.

CONCLUSIONS

Whatever their real shortcomings, retail gravity models have been developed in the past decade into a powerful technique for interpreting the behaviour of aggregations of people at a macro scale.

They still appear to be the best means available to date for evaluating a number of shopping centre proposals at one time.

They represent the only methodology aimed at determining the impact of new centres on the sales of all other existing shopping facilities in a municipality.

The flexibility of the retail model for testing a wide variety of alternative patterns of retail location remains largely unchallenged.

The gravity model's open-system approach and its underlying principle of choice behaviour makes it unnecessary to arbitrarily derive an exclusive trade area for each individual centre.

Of the methods currently developed for studying retail area structure, the concepts of the retail model are the most sensitive to the problems of bridging the gap that exists between strictly empirical analysis and the development of a true model of individual consumer choice behaviour from which parameter values may be estimated directly.

Huff's introduction of a probabilistic consumer-choice-behaviour formulation was a significant step forward. It approached the problem of evaluating and predicting the size of retail centres in a given locational pattern from a consideration of the consumer's spatial behaviour.

Huff acknowledged that consumers do not appear to inexorably patronize the nearest centre by developing a conceptual framework in which it is possible to assess the probabilities of choice made by consumers among a series of competing centres varying in size and separated by unequal distances.

The notion of non-uniqueness in consumer shopping patterns differed significantly from all previous approaches. Both the subjective evaluation methods of Central Place Theory and trade area analysis, and the early retail gravity models explicitly or implicitly assumed exclusive trading areas. Instead, Huff described trade areas in terms of a series of radial zonal probability contours, and not as a fixed line circumscribing a shopping centre.

The probability formulations of the retail model offer a significant improvement over earlier models. They replicate the interaction between a continuous population distribution and a large number of shopping centres representing change from a two-centre interaction model to a many-centred interaction model. As a consequence, there has been a change in emphasis from the market area of the seller to the shopping area of the buyer.

The Huff, Lakshmanan and Hansen, and Cullen versions all permit the evaluation of a system of commercial shopping centres at one time. They make it possible to conduct policy experiments by adjusting the variables within the model to discover instantaneously the effects of various alternatives and assumptions. These features make the method a very valuable tool for planners and an important source of information for government decision makers.

A great deal of exciting new work has taken place in England on extensions of the retail model to incorporate all levels of the shopping hierarchy and the multiple groups of trading areas found in large poly-centred urban regions. Much of this material has now been made available (Wade 1973).

Further progress in testing these novel applications in Ontario can be expected. The implications for resolving retail location problems at a municipal and regional level are readily apparent, particularly for those concerned with developing planning policy guidelines for the orderly growth and development of retail facilities within newly created regional governments.

Further details of the options which are available to the planner are discussed in the case studies chapter. Instructions on their use can be found in the *Technical Appendix*.

3 The Case Study Municipalities

Purpose and Selection of Municipalities

Applications of retail modelling were made in two Ontario municipalities during the course of the study. Both the Huff and Cullen versions were tested in each municipality.

The purpose of the applications was to see to what degree the models were able to provide answers to the sets of planning and policy questions posed in Chapter 1.

The case study municipalities were selected on the basis of their size, complexity, availability of information, and the degree of interest shown by the staffs of the planning boards concerned.

Belleville was one of the centres chosen for study. Considerable information about the retail trade area of Belleville was already available from *Shopping Centre Decisions: Evaluation Guides*, and from a trade area analysis conducted in 1969 prior to the opening of the Quinte Mall. Thus a convenient basis was available for testing the predictive capability of the retail models.

The second location selected was the area of the Central Ontario Joint Planning Board. While not a municipality in the strict sense, it was apparent at the time of the study (summer 1972) that the area under the Board's jurisdiction would be central to whatever boundaries were eventually drawn for the Regional Municipality of Durham announced at the time and now established.

The Board had recently completed a full inventory of retail and service floorspace. Moreover, the Oshawa Area Planning and

Development Study provided a rich source of data on population and economic growth potential. The planning board staffs of both municipalities were keenly interested in participating in the study.

Study Approach

A general hypothesis was formulated about the capabilities of the retail model:

> Retail models are capable of evaluating a wide range of alternative arrangements for the provision of retail shopping facilities under varying assumptions about future travel times and distances, levels of retail expenditure, and population growth rates, distributions and densities.

The validity of this postulation was tested through a number of working hypotheses related to the specific capabilities of the models. It was possible to make comparisons between models and between case studies by testing the Huff and Cullen versions of the retail model in the two case study municipalities over a number of time periods.

Here are the seven working hypotheses that formed the basis for the testing conducted in each municipality:

1. Measures of attractiveness, distance, consumer expenditure and shopping centre sales are available for Ontario municipalities in enough detail and at an acceptable standard of reliability to allow the models to operate.
2. The models, when calibrated, provide a reasonable replication of existing patterns of retail trade in the case study municipalities.
3. The calibrated models have a short-term predictive capability sufficient to make valid projections for at least five years into the future and for longer periods where an adequate basis is available for predicting all the factors that enter into the models.
4. The models indicate the probable consequences of introducing an added centre or an expanded centre into the municipality.
5. The models produce a useful comparative measure of the levels of service to customers provided by alternative possible

REGIONAL SETTING OF STUDY AREAS

MAP 3-1

locations.

6. The models produce a useful comparative measure of the productivity for retailers provided by alternative locations and alternative sizes of centres.

7. The levels of customer flow and expenditure flow between residential areas and shopping centres closely approximate known conditions.

The Use of Terms

It is often difficult in studies of this nature to clarify the distinctions between planning boards and their staffs, and among the legally defined boundaries of the planning area, the municipalities concerned, and the trade area that has been defined for study purposes.

In this chapter, the municipal agencies with which the study team dealt were the staffs of the relevant planning boards. For simplicity in presentation the distinction between staffs and boards has been abandoned and only the board referred to. In Oshawa, for example, it was the staff of the Central Ontario Joint Planning Board who were consulted. The report refers simply to Oshawa or the Board. Area is used as a reference to the planning area of the COJPB as adjusted for purposes of the study.

Similarly, Belleville is used when referring to the trade area boundaries surrounding Belleville as defined in the study and not to the boundaries of the Belleville Planning Board. In actual fact, the study team worked with the staff of the Quinte Planning Board.

Moreover, the boundaries of the Quinte Planning Board's planning area do not correspond to the trade area boundaries of Belleville as used in this study. Accompanying maps have been provided in the text to make sure that the boundaries used for purposes of defining areas for this study are clear (Maps 3-2, 3-3 and 3-4).

THE OSHAWA CASE STUDY

Sources of Data

1. Study Area

The area of market influence of the retail facilities in the Oshawa area corresponds closely to the boundaries established for the Central Ontario Joint Planning Board. The boundaries established for the study were accepted as those of the Board. They encompass a relatively self-contained regional trade area influenced by Metropolitan Toronto to the west (Fig. 3-1).

2. Zones

The Oshawa area had been divided into 67 Basic Planning Units of varying size. The smaller sized units occur in the more densely populated urban areas and the larger sized units in the rural areas. The number, size, and population in each of these units justified their use as population zones for the study (Fig. 3-2).

3. Centres

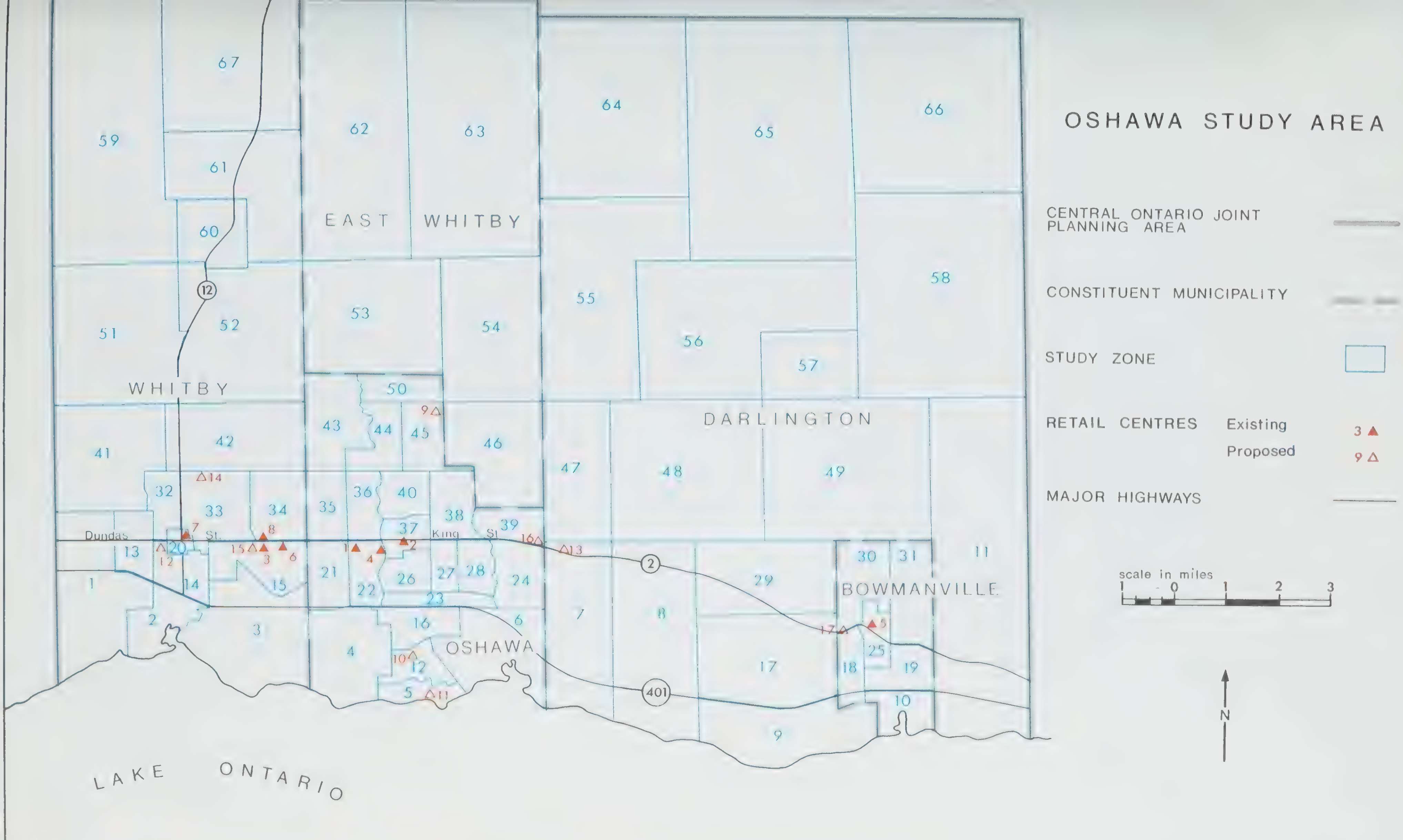
An extensive commercial inventory was completed and published for the study area in the spring of 1972. As a consequence, shopping centre floorspace information was available at the required level of detail.

A review of the survey established 45,000 square feet of leasable area as the smallest size for a centre to be included in the study. The eight centres over this size provided a range of comparison and shopping goods large enough to be influential at a community or regional level.

Where the floorspace was below 45,000 square feet, the predominant proportion of the total floorspace was devoted to food. Centres in this lower category appeared to have a strong local influence but did not seem to have a significant impact at a regional scale.

4. Floorspace Estimates

Floorspace estimates for 1971, both for Food and DSTM (Department Store Type Merchandise), were taken from the Board's



OSHAWA STUDY AREA
CENTRAL ONTARIO JOINT PLANNING AREA
CONSTITUENT MUNICIPALITY
STUDY ZONE
RETAIL CENTRES
Existing 3
Proposed 9
MAJOR HIGHWAYS
scale in miles
1 0 1 2 3
N
EAST WHITBY
WHITBY
DARLINGTON
BOWMANVILLE
OSHAWA
Dundas St.
King St.
LAKE ONTARIO
1972

MAP 3-2

1972 report on commercial structure. Personal service floorspace was deleted from both the planned and unplanned centres. It was found that the majority of personal service floorspace was located within the small unplanned centres not included in the centres to be studied.

Floorspace figures for 1966, 1976 and 1981 were provided by the Board. The 1966 figures were prepared by examining the opening or expansion dates of existing centres and recreating the 1966 centre sizes and locations.

The figures for 1976 and 1981 on possible future centres, and their number, location, and floorspace, were confined to those that had been proposed by the constituent planning boards in the area or discussed by private developers with them (Table 3-1). No other detailed examination of future retail floorspace requirements was undertaken.

5. Zonal Population

Zonal populations for the study years 1971 through 1981 were expressed in terms of households. As part of a planning information system, the Board had collected information by households for all 67 zones for the year 1971. Estimates of the total number of households in 1976 and 1981 were based on planning studies and growth projections for the area. Distribution among zones was provided by the Board through reference to local official plans and other planning documents in their possession.

6. Distance Estimates

The Board prepared a travel-time matrix from recent traffic studies simulating the 1971 situation. Times were indicated for all junction-to-junction links covering routes from each zone to each centre. It was assumed that travel times from the zone centroids to centres would remain unchanged up to 1976. This assumption was later extended to 1981.

The use of straight-line distances in place of a travel-time matrix is possible in the Huff version of the model. A test of this aspect of the model was considered to be valid in Oshawa because of the more uniform size of the population zones. Straight-line distance measures were computed from each zone to each centre

internally to the Huff program from grid co-ordinates of the centroids of each zone and each centre determined by the study team.

The population centroids of zones are likely to shift over time. It would be preferable to take these shifts into account but it was not possible to do so in this study.

7. Income Estimates

The derivation of 1971 income information by household for each of the 67 study zones proved to be a very difficult procedure. Some income information was available from earlier transportation studies, from other population information known to the Board, from federal tax statistics, and from the knowledge of local and provincial agencies and informed officials.

A random sample of family incomes for selected zones was also undertaken as a means of validating the estimates for 1971 through the co-operation of the Area Credit Bureau. The final average household income figures for each zone were arrived at from the survey by applying a family/household ratio.

8. Food and DSTM Expenditures

The proportion of household income available for retail spending was derived by reference to *Family Expenditures in Canada, 1969*. The percentage of total income spent on retail goods was calculated for each level of income. The total income per household for each zone was then adjusted by the approximate percentages to estimate Food and DSTM expenditures per household.

The Financial Post's *Survey of Markets 1971* reported that Personal Disposable Income for Oshawa was 16.3 percent greater than the Ontario average while retail spending was only 10.6 percent above the provincial average.

These figures suggest that there is a five to six percent net outflow of potential expenditures on retail goods. It was estimated that 100 percent of the potential Food expenditures are made within the study area. As a consequence, the income available for DSTM purchases in each zone had to be reduced enough to ensure that total expenditures would equal total sales.

TABLE 3-1

OSHAWA CASE STUDY

OPTIONS TESTED

CENTRES	1971	1976-Opt 1	1976-Opt 2	1976-Opt 3	1981-Opt 1	1981-Opt 2	1981-Opt 3
1. Oshawa Centre	481,350	481,350	481,350	481,350	481,350	481,350	481,350
2. Oshawa C.B.D.	241,260	241,260	241,260	241,260	241,260	241,260	241,260
3. Whitby Mall	135,390	135,390	135,390	135,390	135,390	135,390	135,390
4. Mid Town Mall	117,730	117,730	117,730	117,730	117,730	117,730	117,730
5. Bowmanville C.B.D.	89,160	89,160	89,160	89,160	89,160	89,160	89,160
6. K-Mart Plaza	110,060	110,060	110,060	110,060	110,060	110,060	110,060
7. Whitby C.B.D.	74,910	74,910	74,910	74,910	74,910	74,910	74,910
8. Dundas St. E. (Whitby)	47,670	47,670	47,670	47,670	47,670	47,670	47,670
9. Western Auto Parts (Oshawa)		125,000	125,000	125,000	125,000	125,000	125,000
10. Valiant Property Management (Oshawa)		73,800	73,800	73,800	73,800	73,800	73,800
11. F & T Developments (Oshawa)				145,900			145,900
12. S.W. corner of Dundas W. & Francis St. (Whitby)				80,000			80,000
13. Riznek Construction (Darlington Twp.)					107,000	107,000	107,000
14. Bradley Farm (Whitby)					200,000	200,000	200,000
15. CBC Developments (Whitby)		200,000			200,000		
16. N.W. corner Townline Rd. & King (Oshawa)			125,000			125,000	
17. Western Town boundary & Hwy 2 (Bowmanville)			50,000			50,000	
TOTAL	1,297,530	1,696,330	1,671,330	1,722,230	2,003,330	1,978,330	2,029,230

The final Food and DSTM zonal figures for 1971 were then increased by 1.5 percent per annum to account for increases in 1976 and 1981 expenditures in real dollars. A 5.7 percent net outflow was held constant over the study period.

9. Estimates of Centre Sales

Further reductions in available Food and DSTM expenditures per household were required because the group of centres under consideration represented less than the total available shopping floorspace.

Food and DSTM floorspaces for the eight centres were expressed separately as ratios of the total Food and DSTM floorspace in the area. The estimated average per household expenditures on Food and DSTM were then reduced by these ratios for 1971, 1976, and 1981.

Estimated actual sales for the eight centres in the area were calculated by multiplying the Food and DSTM floorspace in each centre by estimates of sales per square foot varying from $110 to $120 for food and from $50 to $60 for DSTM. At levels of sales of $120 and $60 respectively, the estimated actual sales for the eight centres were $93,500,000.

When the households in each zone were multiplied by the corresponding estimated 1971 Food and DSTM expenditures per household the calculated sales potential was approximately $93,000,000.

CONCLUSIONS - DATA SOURCES

The data needs of the retail models are extensive. In Oshawa it was found that there was little difficulty in establishing a suitable set of trade area boundaries, in defining statistical areas suitable in number and size for use as population zones, in delineating centres, and in measuring the appropriate floorspaces, zonal populations and travel-time distances.

Difficulties arose, however, in measuring the retail expenditures of households in each of the population zones and estimating the actual sales of shopping centres.

Fortunately, the models are constrained in such a way that total sales in the centres included must equal total expenditures available. By carefully estimating each total separately, a

reasonable measure of the validity of the estimates can be obtained.

In Oshawa, for example, the difference between total expenditures calculated from estimates for 67 zones to total retail sales derived from floorspace measures and sales per square foot was less than half of one percent.

Part of the reason for the availability of usable data in Oshawa was the Board's awareness of the fine level of detailed planning information that is required to support regional planning policies and to measure their impact on small zones within the area. Problems of estimating zonal incomes and expenditures are found in many planning studies.

Similar problems of approximating actual sales for individual centres do not appear to have been resolved elsewhere. Both kinds of problems are common to trade area analysis and retail models although retail models appear to have the advantage of requiring that detailed checks be made on the validity of the estimates entering into the program.

It can be concluded that Oshawa had adequate information sources available to provide the data required to operate the model. Additional research on means of estimating incomes and expenditures for small statistical areas and on better ways of approximating actual centre sales is indicated, although the methods used in Oshawa appear to be more refined than those found in comparable studies.

Options Tested

The two versions of the retail model were tested using Oshawa data. The decisions on which sets of options to test were made in close collaboration with the Board. The Board subsequently asked the study team to incorporate only selected options.

Their suggestions included considering which existing retail centres might expand, which of the centres might be operational by 1976 and 1981, and which combinations of centres and sizes seemed most reasonable.

The option decisions were, in effect, an attempt by the board to anticipate or simulate the future retail structure within the study area from information available to them.

Table 3-1 provides a summary of all the options tested and the corresponding total floorspace.

Map 3-2 depicts the location of each retail centre listed in Table 3-1. It is worth noting the relationship of the centres to major transportation corridors through the area and, thus, to major shopping complexes on the eastern periphery of Metropolitan Toronto.

The results of only two options beyond 1971 are discussed here although the results of tests of all options were made available to the Board.

A total of twelve shopping locations were considered in 1976 - Option 3 of which Valiant Property Management (Oshawa), Western Auto Parts (Oshawa), F & T Developments and the S. W. Corner of Dundas West and Francis St. (Whitby) are additions to the 1971 inventory.

The sizes of the original eight centres were held constant for 1976 - Option 3, no growth or reduction in retail floorspace for those eight centres.

The 424,700 square feet of retail space added by 1976 represents a further decentralization of retail activity within the area. But the largest share, 63 percent of the total added, was situated in Oshawa itself.

A review of 1981 - Option 3 suggests the possibility of a further increase in the amount and dispersion of retail floorspace within the study area. Fourteen retail centres are included representing an addition of two new centres over the 1976 level. The two new centres, Riznek Construction (Darlington Township) and Bradley Farm (Whitby) provide for a retail floorspace increment of 307,000 square feet. The floorspace levels of the other twelve centres were held constant beyond those shown in 1976 - Option 3.

Calibration

The Huff version was calibrated on 1971 data by varying the parameter value from 0.0 to 2.0. With $\lambda = 0.0$, the model produced a nearly perfect fit between calculated and actual sales confirming the "bogus calibration" characteristic of the process. When $\lambda = 0.75$, an acceptable fit was obtained. The fluctuations between calculated and actual sales on either side of the calibrated value

were less pronounced than those observed in the Cullen model. The centres were appropriately ranked in order of their sales magnitudes.

The Cullen version was calibrated on 1971 data varying the value of α in steps of .001 and the λ value in steps of .005. A minimum in the summed difference squared between calculated and actual sales occurred when α was set at 0.995 and λ at 0.011. The values on either side of this calibration point produced fits between calculated and actual sales that were markedly different.

The summary site information for Oshawa for 1971 at the calibrated value of lambda (λ) using the Huff version is shown in Table 3-3. The comparable summary for the Cullen version is shown in Table 3-4. Differences can be accounted for by the fact that in Table 3-3 an average of $72.00 per square foot was applied to all centres to estimate the actual sales. In the Cullen version separate sales-per-square-foot values were applied to the Food and DSTM components to estimate actual sales. A review of calculated and actual sales suggests that the Cullen version gave a better replication of what is estimated to be the pattern of retail shopping in the Oshawa area.

Table 3-5 is included to show the effects on summary site output when straight-line distances have been calculated internally using grid co-ordinates in place of a travel-time matrix. A comparison of Table 3-5 with Table 3-3 reveals only slight variation between the calculated and actual sales levels for individual centres.

It might be suggested that in the Oshawa situation there is little difference regardless of which measure is used. However, the significance of the differences has not been established. It can be assumed that if straight-line distances were used throughout the calibration, some small adjustment in parameter values would have resulted.

It can only be concluded that the use of either straight-line or travel-time distances should be consistent within a given study. Further research on this problem is indicated.

Predictive Capability

The predictive capability of the model was tested by holding

the calibrated parameter values constant and attempting to reproduce a known situation five years ahead, a forecast, or five years behind, a backcast. In Oshawa, a backcast was undertaken from 1971 to 1966 -- a prediction of the 1966 situation using 1971 parameters and 1966 data.

Tables 3-6 and 3-7 illustrate the results of the backcast for the Huff and Cullen models. The Huff backcast was adequately reliable for the largest centre, but relationships and rankings were lost for the remainder. In the Cullen backcast, when allowance is made for the difference between total synthesized sales and actual sales, the goodness of fit is remarkable.

It can be concluded that for Oshawa the Cullen version confirmed the short-term predictive capability of the retail model. The Huff version was somewhat less reliable. It was apparent that the Huff version would be improved if the program was adjusted to allow separate sales-per-square-foot estimates to be applied to the Food and DSTM floorspace components of each centre when estimating actual sales. This adjustment has now been made.

Impact of New Centres

Tables 3-8 and 3-9 show the results of the use of the Huff and Cullen versions to evaluate proposals for additional centres to meet the need for added retail floorspace arising from the increased household and the increases in the level of real income per household projected in this study.

The arrangements proposed by the board to meet the needs created by a sales increase of about $54 million, from $93 million in 1971, (Tables 3-3, 3-4) to $147 million in 1976 (Tables 3-8, 3-9) fall short by about $22 million -- the difference between calculated and actual sales.

At a level of $72 per square foot average for Food and DSTM space this would suggest that there is room for an additional 300,000 square feet of retail space by 1976 beyond that suggested in 1976 - Option 3 (Table 3-1).

In effect, two million square feet of added retail floorspace will be required between 1971 and 1976 if the predicted population increases and income levels are matched, and if consumers are to

continue to have comparable levels of retail shopping facilities available to them.

The underestimation of the amount of retail floorspace required to meet future needs could have been overcome if the model had been used as a means of projecting total space needs. This requires special reliance on the household and income projections. In Oshawa these appeared to be sufficiently robust that this use of the model might have been explored if resources had permitted.

Table 3-9 also indicates that the largest decline in market share will occur in the Oshawa Centre, from 35.49 percent to 26.27 percent. It would be interesting to rerun both models to see what the consequences would be of adding the required additional 300,000 square feet in the City of Oshawa or elsewhere.

The fact that the option table did not provide sufficient additional floorspace is reflected in the sales-per-square-foot figures. Calculated sales per square foot climb to about $13 above the level that would be expected if retail productivity per square foot remained at the 1971 levels in real dollars.

Similar forecasts were made for 1981. 1981 - Option 3 indicates a shortfall of $70 million in real dollars over the 1981 requirements, reflecting the need for one million square feet of retail space beyond what is provided for in that option (Tables 3-10, 3-11).

An analysis of Tables 3-10 and 3-11 shows a continued drop in the market share for established centres as new centres are opened, and a continued rise in calculated sales per square foot as a result of major under-storing of the area.

Levels of Service

Two measures of level of service are available. The first -- the level of sales per square foot generated -- is provided by both versions of the model. It can be assumed that if the sales per square foot of calculated sales for a centre are beyond what could be reasonably expected, say, $110 per square foot compared to an average for the area of $72, the consumers in the area of the centre are not being well served. Conversely, a less than average sales-per-square-foot figure might indicate an overstored condition in a local area.

The second measure is provided only by the Cullen version in the column marked AVTL, or average trip length. When comparing two alternative arrangements of retail floorspace to serve an area population, one measure of service to customers is the average length of the shopping trip for all customers.

In Table 3-4, for example, the average trip length for the shopping pattern represented by the synthesized sales is 10.08 minutes, ranging from a low of 8.32 minutes for Centre 4 to 15.49 minutes for Centre 5. If alternative arrangements of centres are possible -- say, the three options in 1976 or 1981 in Table 3-1 -- the differences in average trip length among the three options could be one basis for selecting one option over another.

Comparative Measures of Retail Productivity

The Oshawa study did not provide a suitable means of illustrating the usefulness of comparative measures of retail productivity because the options suggested for testing did not serve the area adequately. Other uses of sales per square foot as a measure have been mentioned, however, in two previous sections.

Customer and Expenditure Flows

Each of the two versions of the retail model produces information on the amount of retail expenditure available in each zone and on the flows of customers and expenditures from each zone to each centre.

In the case of the Huff version, this information is provided in the form of neighbourhood summaries (Table 3-12). The information that has been provided to the model about the zone is summarized in the first line. A table shows the number of customers, the amount expended in each centre, and the total zonal expenditure as well as other information.

In the case of the Cullen version, similar information is provided in a series of tables. Zonal expenditures are provided as a single table (Table 3-13). Zone-to-centre customer and expenditure flows are shown as matrices (Tables 3-14, 3-15).

The matrix version provided by the Cullen version is more

compact and easier to read. The Huff version provides a neat set of tables but the sheer bulk of the printed results and the added costs in computer time limit their use.

If consumer shopping survey data were available it would be possible to produce two comparable matrices of customer or expenditure flows -- one from survey and one from the output of the calibrated model.

The possibility of doing so in the course of this research was discussed but the costs of the survey were beyond the resources available to the study team. Comparison of the results would do much to confirm the reliability of the retail model. Hopefully, this will be done in future applications.

Conclusions - Oshawa

The conclusions on data needs were discussed earlier. The options suggested for testing did not provide enough additional retail floorspace to match the forecasted needs. This made analysis of the results of testing less rewarding than anticipated.

Both models calibrated easily on the 1971 base year data. The backcast to 1966 confirmed the predictive capability of the models, with greater reliability being shown by the Cullen version.

The shortfall in the total amount of floorspace included in the option to be tested confirmed the potential value of the models for estimating future floorspace needs.

On the basis of the Oshawa study, the Board was provided with a quick analysis of their initial intuitive projections and the means to progressively refine their proposals to a smaller number of feasible solutions. The potential usefulness was shown of measures of service to households, retail productivity, and customer and expenditure flows.

THE BELLEVILLE CASE STUDY

Sources of Data

1. Study Area

The boundaries selected to represent the market area for

BELLEVILLE STUDY AREA

PLANNING AREA

JOINT SUBSIDIARY PLANNING AREA

STUDY ZONE 48

RETAIL CENTRES : Existing 3 ▲ Proposed 9 △

MAP 3-3

Belleville were based on the Board's knowledge of local conditions and on a detailed market analysis done in 1969 by a private consulting firm (Map 3-3). By choosing boundaries identical to those used in the 1969 study of Belleville's market potential, it was possible to compare the results of the trade area analysis and the retail model.

The adopted boundaries can probably be considered conservative by the time that the 1981 projection year is reached. The drawing power of the estimated facilities needed to serve the study area population in 1981 is likely to extend beyond the defined boundaries, particularly to the west and north.

2. Zones

Forty-four wards and subdivisions of wards were adopted as population zones within the corporate boundaries of Belleville (Map 3-4). Ward subdivisions constitute the city's polling districts. They are the smallest unit for which practical retrieval of population data could be achieved by the Board.

Outside the City of Belleville 13 very large zones were established to cover the remainder of the area. These were made up of single urban centres or a combination of townships and smaller municipalities comprising the three large area units defined in the 1969 study, Secondary Trade Area, Tertiary Trade Area A, and Tertiary Trade Area B. The concentration of so many zones within Belleville is questionable. A more equal distribution of the number of zones between the inner and outer areas would have been preferable.

3. Centres

A detailed inventory of existing commercial retail facilities was available from the 1969 study. The Board was able to arrive at data for 1966 and 1971 by a careful review of centres opened before and after the 1969 inventory. The majority of major centres in 1966 and 1971 were unplanned. A minimum floorspace of 50,000 square feet was adopted to ensure the general mix of store types and goods in the centres indicated that a community or regional function was being performed.

4. Floorspace Estimates

Floorspace estimates for both Food and DSTM were developed from the 1969 inventory. For the unplanned centres those groups of Food and DSTM stores were included which fulfilled the minimum criteria defined in the consultant's report. Only stores that did meet the standards were felt to contribute to the attractiveness of the unplanned centres.

The size and number of possible future planned centres and their location were obtained through discussions with the board (Table 3-2). Some centres included for consideration arose from past proposals. Some were proposals that were in the early stages of discussion with private developers. Others were of interest to the Board as a means of evaluating alternative patterns of growth and development.

The Food and DSTM floorspace of potential future centres was derived from preliminary submissions made by private developers or from estimates made by the Board.

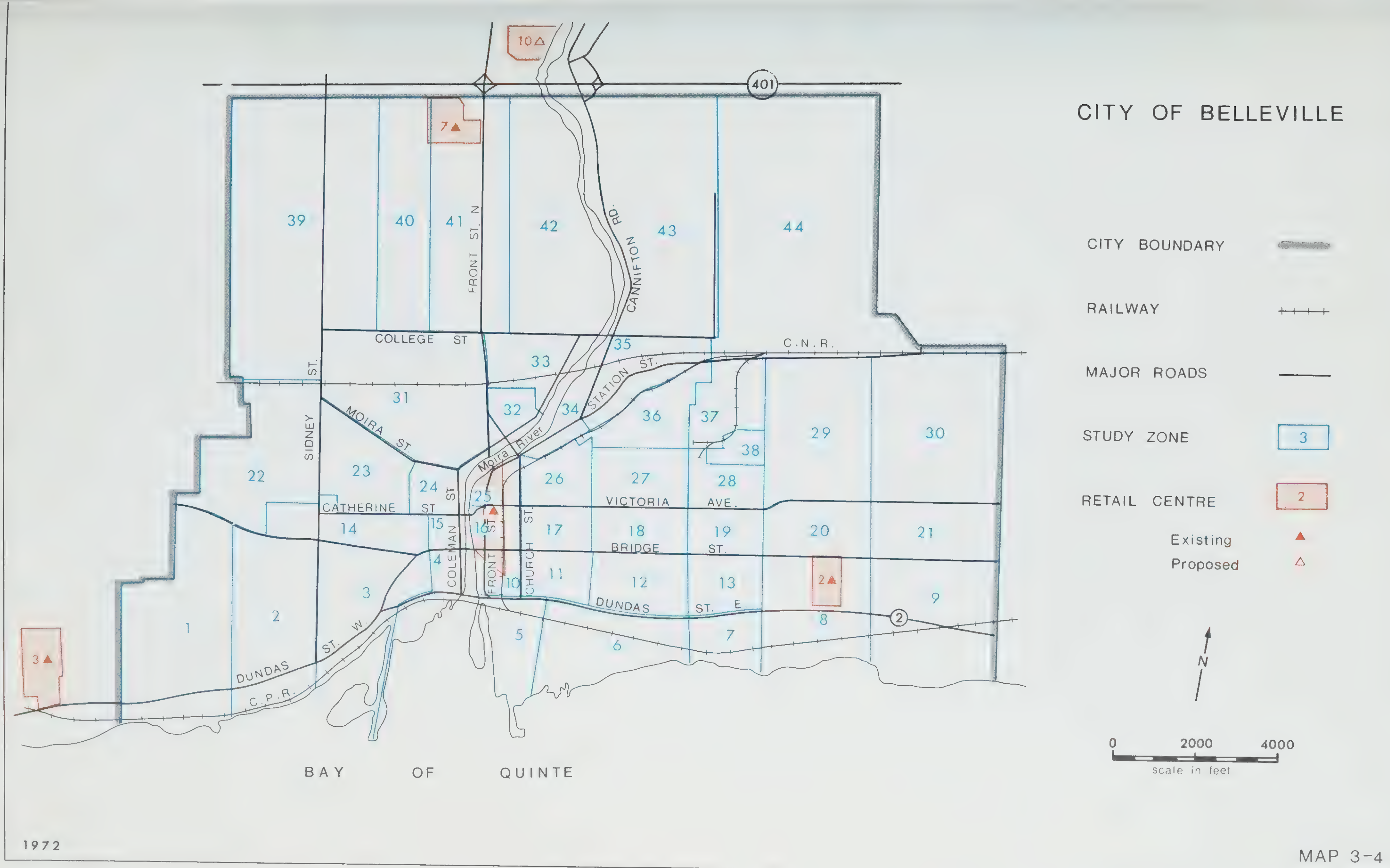
5. Zonal Population

Household information for Belleville was not readily available. In consequence, 1966 and 1971 populations for the 44 zones within Belleville were derived from Statistics Canada reports and local data files. The projections for 1976 and 1981, and their distribution within the corporate area, were supplied by the area planning board using official plan references and a labour force index-population ratio.

Populations for 1966 and 1971 in the 13 outer zones were taken from the provincial municipal directories. 1976 and 1981 population projections were based on estimated ratios reported during the 1969 market study. Independent estimates were rejected in order to maintain as great a degree of comparability as possible between the trade area study and the retail model results.

6. Distance Estimates

A travel-time matrix was not available for Belleville. As an alternative, straight-line distances along major roads from each zonal centroid to each centre were measured in decimal inches from two differently scaled maps, one for Belleville and the other for


CITY OF BELLEVILLE
CITY BOUNDARY
RAILWAY
MAJOR ROADS
STUDY ZONE
RETAIL CENTRE
Existing
Proposed
N
0 2000 4000
scale in feet
401
2
C.N.R.
C.P.R.
COLLEGE ST
FRONT ST. N
CANNIFTON RD.
STATION ST.
MOIRA ST.
Moira River
SIDNEY ST.
CATHERINE ST
COLEMAN ST
FRONT ST
CHURCH ST.
VICTORIA AVE.
BRIDGE ST.
DUNDAS ST. E.
DUNDAS ST. W.
BAY OF QUINTE
1972
MAP 3-4

the peripheral areas.

This required a scale conversion procedure. Converted figures were then added to indicate the full distances between the zones and centres on the two map schedules. The procedure here accommodated the many small zones within Belleville and the few macro-scale zones in the very much larger outer area. The resulting measures were employed as actual distances in the tests of both versions.

Although the Huff version of the model has the capability to calculate straight-line distances internally, given grid co-ordinates for zone centroids and centres, the differences in scale of the two maps used effectively precluded this option.

To help overcome the limitations imposed by the use of actual distances, estimated zone centroids were placed as close as possible to the centres of population gravity. In some cases the population gravity centroid varied markedly from the physical centre. The aim was to better reflect the actual distances travelled by people living in the zones to get to each of the centres. Travel distances were held fixed over the study period. In reality, changes would likely occur due to changes in road alignments, shifts in population centroids, and so forth.

7. Income Estimates

Separate estimates of per capita expenditures for Food and DSTM categories for each of the four study years were taken from the 1969 study. Income data appear to be the least refined of all data collected. Separate estimates had been made only for the four broad areal units constituting the total study area -- Belleville, Secondary Trade Area, Tertiary Trade Area A, and Tertiary Trade Area B.

All 44 zones within Belleville were assigned a single average per capita figure for Food and for DSTM expenditures in line with the 1969 report, notwithstanding the variations in zonal per capita incomes that could be expected.

Estimates for the remaining 13 zones also had to be aggregated for each of the three remaining areal units and each of the 13 zones assigned the corresponding average expenditure values. Projected per capita Food and DSTM expenditures for 1976 and 1981 were

calculated in real dollar terms to avoid the complication of the effects of inflation on sales forecasts.

8. Food and DSTM Expenditures

Estimating inflow or outflow of retail expenditures across the area boundary was difficult. It was estimated that 100 percent of the per capita expenditure on Food would likely remain within the study area. This assumption would not hold, however, for DSTM goods. The 1969 study estimated a 1971 outflow of DSTM spending from the four areal units of 20 percent for Belleville, 25 percent for the Secondary Trade Area and 30 percent for Tertiary Trade Areas A and B. Comparable levels for 1966 proved to be about five percent greater across the board.

With construction of additional planned centres projected for 1976 and 1981 it was assumed that the outflow could be reduced by a further five percent, but little hope was held for any further reduction. A certain amount of spending on specified classes of goods will probably always occur outside the Belleville study area by mail order and in nearby large metropolitan centres such as Toronto or even Kingston.

9. Estimates of Centre Sales

A further step was to determine what percentage of total potential expenditure was available to the centres being studied.

Ratios of the total amount of floorspace for all the six or seven centres in the study to the total floorspace in the study area were calculated separately for Food and DSTM for each study year.

The ratios were then employed to reduce per capita expenditures for Food and DSTM in each of the zones for 1966, 1971, 1976, and 1981 to represent the actual amount available.

When the total population in each zone was multiplied by its corresponding per capita expenditure, the 1966 estimate for Food and DSTM purchases was $49,500,000. The available floorspace multiplied by sales-per-square-foot ratios of $40 and $100 for DSTM and Food in all centres (except for one new planned centre where $60 and $110 were applied) was $49,400,000.

OPTIONS TESTED

CENTRE	OPTION 1966	1971	1976-1	1976-2	1981-1	1981-2	1981-3	1981-4	1981-5	1981-6	1981-7
1. Belleville Central Business District	344,800	342,000	342,000	245,000	342,000	170,000	170,000	341,200	170,000	341,200	341,200
2. Belleville Plaza	98,600	98,600	168,600	168,600	168,600	168,600	168,600	168,600	168,600	168,600	168,600
3. Towers	71,000	71,000	71,000	71,000	71,000	71,000	71,000	71,000	71,000	71,000	71,000
4. Trenton	152,900	152,900	152,900	152,900	152,900	152,900	152,900	152,900	152,900	152,900	152,900
5. Picton	49,400	49,400	49,400	49,400	49,400	49,400	49,400	49,400	49,400	49,400	49,400
6. Napanee	68,300	68,300	68,300	68,300	68,300	68,300	68,300	68,300	68,300	68,300	68,300
7. Quinte Mall		186,800	309,300	309,300	309,300	309,300	186,800	186,800	309,300	309,300	309,300
8. Trenton New Centre					100,000	100,000	100,000	100,000	100,000	100,000	
9. Leasehold Proposed Mall									121,400	121,400	121,400
10. McFarland Plaza							95,800	95,800			
Total Floor space	785,000	969,000	1,161,500	1,064,500	1,261,500	1,089,500	1,062,800	1,234,000	1,210,900	1,382,100	1,282,100

For 1971, the comparable figures were $61,300,000 and $61,800,000 respectively.

In both periods expenditure and sales appeared to be in reasonable balance, and the estimates employed were considered to be independently verified.

CONCLUSIONS - DATA SOURCES

Problems with data sources in Belleville were extensive. The availability of information from the 1969 study proved to be extremely helpful in some ways and created great difficulty in others.

The problem of defining boundaries was much simplified as was the calculation of outflows and inflows of sales across area boundaries.

The inventory of retail floorspace was excellent, but the lack of household information meant reliance on per capita expenditure data which was considered less suitable for purposes of calculating spending characteristics in a population.

The difficulty of estimating actual sales for individual centres remains the "bête noire" of retail studies of any type.

Some concern exists about the constraints imposed by having to allocate identical per capita expenditure figures over four large trade areas to 57 zones. Similarly, the number of zones concentrated in Belleville compared to the much smaller number covering the balance of the area is recognized as creating an added problem. While a large number of zones is preferable, the distribution of zones and the size of the population in each needs to be carefully balanced.

The experience of the Board with the 1969 study and the subsequent Ontario Municipal Board hearings (discussed in *Shopping Centre Decisions: Evaluation Guides*) appears to have made the Board conscious of the need for careful consideration of the retail component in planning studies. As a consequence, the Board was able to provide the study team with help in the interpretation of data for their area and in the preparation of testable options for future years that is not often available in other jurisdictions.

It can be concluded that the sources consulted provided only the minimum information needed to operate the model. Considerably greater refinement in detail would have been preferred. The existence of the trade area analysis done in 1969 reduced the amount of time required for data preparation. In addition, it provided invaluable independent verification of many of the estimates used.

Options Tested

Retail models are assumed to have the capability of predicting the impact of new proposed shopping centre sites on existing retail centres or the implications of a redistribution of floorspace among the centres -- for example, a gradual reduction of the proportion of space in the central business district and an increase in the amount of space in suburban shopping centres. Several options were tested for the projection year 1976 and 1981 in exploring this capability of the model.

Decisions were made as to what options the study should test in advance of initiating any tests on the computer. The criteria used included considering which retail centres should be studied, what additional retail floorspace in new or expanded centres could be envisaged by 1976 or 1981, and what combination of centres and variation in floorspace seemed to make the most planning sense. The result was a proposal by the Board of the options to be tested (Table 3-2).

Identical options were tested for the two versions of the retail model employed in the study. Table 3-2 presents a complete summary of all the centres considered by the various options suggested to the study team and the corresponding total floorspace. The location of each centre relative to the population zones within the study area is illustrated in Maps 3-3 and 3-4.

The discussion of results is limited to an analysis of the years 1966, 1971, 1976 - Option 1 and 1981 - Option 6. Full results, however, were made available to Belleville for all options listed in Table 3-2.

The base year 1966 was used to evaluate the sales levels of the Belleville C.B.D., Belleville Plaza, Towers, Trenton, Picton

and Napanee. By 1971, the number of centres had increased to seven following the opening of the Quinte Mall in 1970. The new centre provided an increase of 186,800 square feet. All the original centres remained static except for the Belleville C.B.D. A minor reduction occurred in floorspace from 344,800 to 342,000 square feet.

The anticipated changes for 1976 - Option 1 were confined to increases in retail floorspace for the Belleville Plaza, 98,600 to 168,600 square feet, and the Quinte Mall, 186,800 to 309,300 square feet.

For 1981, seven options were decided upon and tested by the two retail gravity models. 1981 - Option 6 provides the best illustration of results. Nine retail centres were considered, added centres being the Trenton New Centre and the Leasehold Proposed Plans. A further minor reduction is shown for C.B.D. floorspace. The Board wished to establish the consequences of significant growth and further dispersion of retail space by 1981.

The options included in Table 3-2 represent only a few of the many possibilities that could have been tested by either of the two versions of the retail model. The selection of specific options by Belleville was constrained, among other reasons, by the amount of land available or desirable for commercial development, tentative retail proposals already before the Board, the ownership of certain lands, the owners' aspirations for commercial use, and the possibility of some population growth in other communities within the retail sphere of influence of Belleville that might reduce the need for retail developments in Belleville itself.

Calibration

The Huff model was calibrated on 1966 data by varying the parameter value from 0.0 to 2.0. The best fit between actual and calculated sales appeared to occur at $\lambda = 0.88$. At a value of 0.0, the model produced a near perfect fit, the "bogus calibration" fit. The sensitivity of the model to distance was eliminated and sales were distributed from zones to centres in strict proportion to size. A proper rank-order was maintained for calculated and actual sales for all centres, further justifying the assumption of a lambda value of 0.88 (Table 3-16).

The Cullen model calibrated on the 1966 Belleville data by employing two parameters, alpha (α) and lambda (λ). The best fit, where actual and calculated sales were most closely correlated, was found at $\alpha = 0.975$ and $\lambda = 0.036$.

The importance of maintaining a proper rank-order throughout the calibration process has already been discussed. The correspondence of rank-order can be seen by comparing the columns labelled SYN SALES and ACT SALES in Table 3-17.

Predictive Capability

After the calibration process was completed in such a way that the rank-ordering was correct and a high degree of fit was obtained for 1966, both versions were pushed forward in time by putting 1971 data in place of 1966 data (Tables 3-18, 3-19).

An analysis of the results indicates how well each version has done in predicting the 1971 retail situation as it was foreseen in 1966, that is, their predictive validity.

For 1971 both the Huff and Cullen versions were able to predict the retail situation with considerable accuracy. In each case the rank-order of centres changed slightly. For example, in the Huff model the rank-order was slightly altered between the first and sixth centres. The shift in rank-order was not considered enough to invalidate the predictive ability of the models.

Impact of New Centres

The results of the use of the Huff and Cullen versions to evaluate the consequences of the introduction of new centres at specified locations is illustrated in Tables 3-18 and 3-19.

It was suggested by the proponents of Quinte Mall during the Ontario Municipal Board hearings that preceded approval of the centre that the opening of the new mall would help or at least not harm Belleville C.B.D.

If Table 3-18 is compared with Table 3-16 it will be seen that in the Huff version Belleville C.B.D., Centre 1, has been allocated sales in 1971 in excess of the 1966 level in spite of the introduction of Quinte Mall, Centre 7, which was allocated about

$10.4 million in sales.

In discussion with the Board in 1972, it was confirmed that the C.B.D. merchants did not appear to have suffered a loss in total dollar sales. This was not true for all merchants nor was it true for the relative shares of business being captured by Belleville C.B.D.

The Cullen version showed slightly different results with sales for the C.B.D. down about $1.0 million. At the same time it was reported that the trade area boundaries shown in the 1969 study had expanded because of the cumulative attraction of the new Quinte Mall and an attractive and well merchandised downtown.

C.B.D. shopkeepers were said to be serving a significant number of customers from beyond the boundaries of the Secondary Trade Area, particularly towards Peterborough. This would account for the ability of the C.B.D. to increase its sales.

In addition, the extended boundaries would have increased the retail expenditure potential for the whole area and the amount of business that the model would have available to allocate to centres.

The availability of consumer shopping survey data suggested for the Oshawa case study would have been useful in estimating the extent of the shift of trade area boundaries that appeared to occur in Belleville. A careful analysis of consumer shopping trips is once more underscored as an essential part of retail modelling.

The usefulness of the two versions of the retail model in evaluating the impact of new centres appeared to be validated by the results in the Belleville area. Improvements in data and further experience with the operation of the models elsewhere provide additional evidence that this is generally true.

The Belleville experience suggests the advantages to be gained by maintaining a careful watch on results when new centres are opened in major municipalities over a period of two to five years, on a year-by-year basis.

It would appear that the Quinte Mall was built to the right size and at the right time. It would also appear that the cumulative attraction of the new mall and the merchandising strength of the C.B.D. prevented the serious loss of C.B.D. sales that has been experienced elsewhere. The Belleville Board

has confirmed the shortness of the recovery period in discussion with C.B.D. merchants.

The options tested for 1976 and 1981 in Belleville proved to yield excellent results. The amount of floorspace suggested matched the requirements almost exactly. It was possible, therefore, to do a detailed but tentative analysis of the results of the projections.

A preference was given to 1976 - Option 1 over 1976 - Option 2 because of the better fit obtained between calculated sales and actual sales. The magnitude and distribution of retail floorspace used in 1976 - Option 1 better satisfied the projected demand resulting from income and population increases. A review of Table 3-2 will identify the floorspace variations considered in 1976.

For the Huff version, 1976 - Option 1 was tested using the calibrated lambda value of 0.88 and an actual sales-per-square-foot figure of $63. In two instances the desired rank-order between calculated sales and actual sales shifted between 1971 and 1976 (Table 3-20).

The projected expansion of the Quinte Mall and the Belleville Plaza would appear to satisfy the majority of the potential retail demand. In addition, a satisfactory sales level is maintained among all seven centres. There would seem to be no justification for any additional large-scale shopping facilities before 1976, assuming that the anticipated expansion occurs at the two selected sites and that population and incomes increase as predicted.

A review of customer distribution and calculated sales among the seven centres reveals an interesting trend. As suggested in 1971, Belleville C.B.D. will capture an even smaller percentage of the total consumers (30.69%) and of calculated sales (31.72%). Meanwhile, the floorspace additions to the Belleville Plaza and Quinte Mall would increase their percentage share of consumers from 10.16 to 14.30, and 16.90 to 23.80 respectively. Similar increases would also occur in the calculated sales distribution.

In 1976 - Option 1, further expansion of the Belleville Plaza and Quinte Mall could be justified on the basis of the projected income and population forecasts used in this study with some degree of certainty of a non-deleterious impact on the existing retail structure. Any further large-scale shopping centre proposals would

have to be considered premature in light of the 1976 - Option 1 results.

The summary for the Cullen version for 1976 - Option 1 is shown in Table 3-21. By the end of the five-year period total sales increased by approximately $14.5 million, caused by an increase in income and population. The fit for this option is again quite good but not as good as that obtained in the previous two periods.

The increase in demand for retail floorspace was met by two changes in existing retail facilities. The Belleville Plaza increased its floorspace by 70,000 square feet making it the third largest centre. The size of the Quinte Mall increased by 122,500 square feet to a total of 309,300. Quinte Mall at this period was approaching the size of the C.B.D.

It is difficult to determine the effect of a single centre increase when more than one centre is changed within the same time period. If individual effects are to be determined, they must be examined in separate options. In this study the effects are considered in terms of both increases occurring simultaneously.

The C.B.D.'s decline in importance is reflected in the customer and cash flow matrices (Tables 3-26, 3-27). C.B.D. ranked first for 39 of the 57 zones -- a decrease of 12 from 1971. In the zones where the C.B.D. was displaced in rank, its position was relinquished almost exclusively to the Quinte Mall.

It is apparent that when adequate information is available the retail model shows considerable potential for examining the probable consequences of the introduction of new centres at stated years in the future. The analysis of Belleville's 1976 - Option 1 appears to provide a convincing illustration.

Projections to 1981 were also attempted. Seven options were actually tested. The best fit was produced by 1981 - Option 6 which is discussed here.

Using the Huff version it would appear that by 1981 there is substantial indication that an opportunity will exist for the further development of large-scale shopping facilities (Table 3-22).

The summary site information reveals that two plazas -- Trenton New Centre of 100,000 square feet and Leasehold Proposed Plaza of 121,400 square feet -- could be justified and operating by 1981

without any detrimental impact on the sales levels presently enjoyed by the seven existing centres.

The level of sales for the existing centres would increase, maintaining an acceptable sales-per-square-foot ratio. The distribution of consumers and total calculated sales would decrease, however, as a consequence of increasing the number of centres. In effect, the percentage share of the centres would decrease because customers and sales would be redistributed among nine instead of seven centres.

According to the predictions of the Huff version, 1981 - Option 6 seems to maximize overall projected customer shopping satisfaction and best provides a combination of centres to satisfy both regional shopping patterns and intra-urban shopping trips. Any other changes in the retail structure in the interval before 1981 which have not been included in the options tested would obviously invalidate this conclusion.

The testing of 1981 options for the Cullen version confirmed that 1981 - Option 6 appeared to best satisfy the increased retail sales demand of $12 million which was generated in the previous five years by population and income increases (Table 3-23). The fit is again quite good but not as good as in the three previous analyses.

Two centres have been added to the existing seven in order to meet projected floorspace needs. Trenton New Centre has a floorspace of 100,000 square feet which places it sixth in terms of size. The Leasehold Proposed Plaza ranks fifth in size with a floorspace of 121,400 square feet.

It is again necessary to examine the impact of two simultaneous changes in retail facilities. The two new centres would appear to be able to obtain 15.4 percent of the retail market with seven percent going to the Trenton New Centre and 8.4 percent to the larger Leasehold Proposed Plaza.

All of the original seven centres were shown as suffering a decline in percentage share of the retail market. The most significant losses were allocated to the Belleville C.B.D., a 3.7 percent drop, Trenton Centre, a four percent decrease, and the Quinte Mall which declined 3.6 percent. The Napanee Centre seems least affected with a decrease of only 0.5 percent.

In terms of sales per square foot, both of the new centres are projected to come in with below the overall average of $63.50 per square foot. The Leasehold Proposed Plaza reaches only $60.60 per square foot.

The most significant change is a projected decrease of $12.61 per square foot suffered by the Trenton Centre which seems to be caused by the Trenton New Centre. This suggests that a possible over-expansion of retail floorspace in Trenton could result by 1981.

The two largest centres, the Belleville C.B.D. and the Quinte Mall, remain quite stable, each showing a $0.10 increase. Napanee showed an increase of $5.88 which is significant in that it now has the greatest sales-per-square-foot figure -- $80 per square foot. At this point Napanee may be understored in relation to the overstored projection made for Trenton. Thus, there are indications that Napanee could stand on expansion of its retail space by 1981.

The ranking of the Belleville C.B.D. in customer and cash flow matrices remained constant in its number one position in 39 of the 57 zones. The Quinte Mall was again most commonly found in the number two position and, when the C.B.D. slipped from its number one ranking, it was usually replaced by the Quinte Mall.

In the years projected by the Cullen version of the retail model, it appears that the dominance of Belleville's C.B.D. can still be maintained. The proposed new centres and the expansion of existing centres foreseen by the Board would not leave any centre in an untenable competitive situation although Napanee appears to be short of space and Trenton oversupplied.

The outputs of the model contain income and population increases which determine consumer demand. To maintain the validity of any prognostications of this type, continued monitoring of current changes would be essential.

Levels of Service

The Belleville study provides a clear indication of the usefulness of the measures of level of service provided by the model.

In the discussion of 1981 - Option 6 it is apparent that the allocation of retail floorspace to Trenton and Napanee would result

in an overstored and an understored condition respectively.

In this instance the customers in Napanee would not be receiving a level of service comparable to what they had previously experienced. The use of the retail model facilitates this type of determination.

The use of the average-trip-length measure of level of service was employed extensively in the Belleville analysis. The options for 1976 and 1981 all produced enough total retail floorspace to match anticipated demand.

It was possible to compare the average trip length produced by the distribution of retail floorspace reflected in each option to the average trip length produced by all other options. This measure was employed by the study team as one basis for selecting an option to use for purposes of illustration -- the one with the best overall performance.

Comparative Measures of Retail Productivity

The Belleville study produced numerous illustrations of the usefulness of the measure of retail productivity in analyzing particular options or comparing one option against another. This ability of the model would appear helpful to the retail analyst working with a shopping centre developer or planning board.

Customer and Expenditure Flows

The use of zonal expenditure information and zone-to-centre flows of customers and expenditures has already been illustrated in earlier discussion of the Belleville applications. A sample of a Huff neighbourhood summary is included as Table 3-24. The tables produced by the Cullen version of the model are shown as Tables 3-25, 3-26, 3-27. The matrices provided with the Cullen results are easy to follow and have proved to be most helpful when trying to trace faults in the summary tables or to ensure that improbable shopping trips have been adequately constrained in the calibrated version.

Conclusions - Belleville

The sources of data in the Belleville study have already been

discussed. The Belleville case study provided an opportunity to examine the information produced by the model in considerably more detail than was possible in Oshawa.

The calibration procedure worked out easily for both versions and the test of predictive capability showed enough precision that short-term (five year) forecasts could be made with some confidence.

The options suggested for testing in Belleville proved to match the future retail floorspace requirements in all instances. The four options chosen for discussion from among the eleven actually tested show quite clearly that the retail model is capable of giving a perceptive indication of the past and present retail situation in Belleville.

Moreover, it was illustrated how planning decisions about the provision of retail facilities for the future can employ estimates of consumer travel as a means of ensuring adequate levels of customer service and centre viability.

Measures of retail productivity also proved to be useful indications of customer service within the limits of currently available forecasting methods.

Future changes in population, consumer travel patterns, per capita income, per capita retail expenditures, attractiveness factors etc., all have a profound effect on the suitability of retail locations and shopping satisfaction.

The application of the retail model in Belleville appears to show quite adequately how it can assist in reducing uncertainty in retail planning decisions and to suggest quite strongly that the retail model does have a role to play in ensuring a responsive and vital retail segment in the community.

CONCLUSIONS - CASE STUDY MUNICIPALITIES

Sources of Data

1. Floorspace Estimates

In both Oshawa and Belleville it was confirmed that adequate data sources were available to operate both versions of the retail model tested. An up-to-date retail floorspace inventory was

available in both instances, and this proved to be the single most important set of required data. Several tests of the reliability of the inventories were carried out including field survey checks of a few centres and confirmation that sales per square foot for selected trade categories were within acceptable bounds.

2. Zones & Boundaries

The selection of zonal boundaries appears to require some care. In both instances the boundaries of the study area were largely predetermined by previous retail studies. In the case of Oshawa the zones were fairly evenly distributed throughout the area. In Belleville the concentration of zones within the city created an even population distribution throughout the trade area, but a less than satisfactory spatial distribution.

3. Population, Income and Expenditure Estimates

Zonal household figures and expenditures in Oshawa were estimated with a high degree of reliability. Household information was not readily available in Belleville on a zonal basis. A compromise solution was adopted involving the use of zonal population figures. Per capita expenditure figures could not be disaggregated zonally in the Belleville study. The Oshawa data would appear to be superior to the Belleville data in these respects.

4. Distance Estimates

Distance estimates for Oshawa were available from Ministry of Transportation and Communications survey data. For Belleville, distance estimates were scaled directly from maps, a less reliable procedure. A test of the straight-line distance option in the Huff model proved difficult to evaluate in relation to travel-time matrix measures. However, there seemed to be little apparent difference in the allocations of sales in Oshawa when employing measures of straight-line distance calculated internally by the Huff program from grid co-ordinates.

5. Centre Sales

There were no significant differences in the methods used to approximate actual centre sales between the two case study

municipalities. The averaging method used in the Huff version tested would appear to be less satisfactory than the variation in centre sales per square foot available in the Cullen version. This discrepancy has since been corrected. The approximation of actual centre sales still remains an area in need of further study. This is particularly true when the potential sales of contemplated new centres are being evaluated.

6. Options Tested and the Impact of Future Floorspace

A comparison of the two municipalities reveals the significance of the ability to estimate future floorspace requirements in relation to future distributions of population and retail centres. The Belleville table of options allowed a detailed comparison and evaluation of alternatives. In the case of Oshawa, the potential of the model as a means of projecting future floorspace requirements was demonstrated.

7. Comparative Measures and Flows

In Belleville the opportunity to test the comparative measures of level of service, productivity and customer and expenditure flows suggested how the measures could be usefully employed in evaluating alternative locations and centre sizes. In both municipalities it was apparent that the customer and expenditure flow matrices of the calibrated version could have been checked against surveys of customers' shopping behaviour, had they been available. The Huff version of the model allows for the calibration of the model against consumer surveys to ensure that the resulting solution matches observed effects.

8. Comments

The comparative testing that was conducted appears to confirm the principal claims of the usefulness of the retail models. The results reproduced in the case studies have been discussed in some detail.

It is obvious that it would be worthwhile to repeat the studies to make a number of significant adjustments in the data that were provided to the model, and to introduce further variations by a full testing of each of the options available within each version.

The usefulness of doing so was not contemplated within the adopted research design.

In any case, subsequent operational applications of the model in places such as Oxford County, Regional Waterloo, Regional Niagara, Kingston and London benefitted greatly from both the advantages and shortcomings that were revealed in the applications in the case study municipalities.

GLOSSARY OF TERMS - TABLES 3-3 THROUGH 3-27

SITE	The number of the centre in the sequence in which they appear in the data provided to the model.
SIZE	The size of the centre in square feet of gross leasable area or its equivalent for Food and DSTM merchandise.
FOOD	The square footage of Food floorspace in the centre.
DSTM	The square footage of DSTM floorspace in the centre.
AVTL	The average trip length for customers allocated to centres reflecting trip distances weighted by their associated customer flows. The average trip length over the entire study area is shown as a total.
XS,YS	The X and Y grid coordinates of each centre measured in decimal inches from a predetermined origin.
CUST	The number of customers allocated to each centre on the basis of the probabilities calculated by the program.
CAL SLS, SYN SALES	The calculated or synthesized sales. The product of the number of customers from each zone and their average expenditures on Food and DSTM goods.
ACT SLS	The approximation of actual sales derived as a product of floorspace and sales per square foot.

GLOSSARY OF TERMS (CONTINUED)

CS/FT	The calculated sales per square foot, derived by dividing SIZE by CAL SLS.
AS/FT	The actual sales per square foot derived by dividing SIZE by ACT SLS.
HH SH	The share of households or populations attracted to the centre from the total households or population in the area.
CA$SH	The estimate of the share of calculated sales attracted to each centre.
AC$SH	The estimate of the share of actual sales attracted to each centre.

SITE	SIZE	FOOD	DSTM	XS	YS	CUST	CAL SLS	ACT SLS	CS/FT	AS/FT	HH SH	CA$SH	AC$SH
1	481350.	33500.	447850.	7.10	5.30	14597.	35028176.	34657200.	72.77	72.00	37.28	37.68	37.10
2	241260.	20860.	220400.	8.30	5.50	8734.	20550496.	17370720.	85.18	72.00	22.30	22.11	18.59
3	135390.	26180.	109210.	5.10	5.30	3725.	8947430.	9748080.	66.09	72.00	9.51	9.62	10.43
4	117730.	23150.	94580.	7.80	5.30	3579.	8503874.	8476560.	72.23	72.00	9.14	9.15	9.07
5	89160.	16650.	72510.	19.20	3.30	2264.	5015957.	6419520.	56.26	72.00	5.78	5.40	6.87
6	110060.	25240.	84820.	5.60	5.40	2897.	6945319.	7924320.	63.10	72.00	7.40	7.47	8.48
7	74910.	30090.	44820.	3.00	5.50	2072.	4869584.	5393520.	65.01	72.00	5.29	5.24	5.77
8	47670.	1260.	46410.	5.10	5.60	1293.	3105798.	3432240.	65.15	72.00	3.30	3.34	3.67
TOTAL	1297530.	176930.	1120600.			39161.	92966608.	93422160.	71.65	72.00	100.00	100.00	100.00

SITE

Number	Name
1.	Oshawa Centre
2.	Oshawa Central Business District
3,	Whitby Mall
4.	Mid Town Mall
5.	Bowmanville Central Business District
6.	K-Mart Plaza
7.	Whitby Central Business District
8.	Dundas St. East (Whitby)

See Glossary of Terms on preceding pages.

TABLE 3-4 EXISTING RETAIL DISTRIBUTION - (CULLEN)
OSHAWA, ONTARIO - 1971
ALPHA (α) = 0.995 - LAMBDA (λ) = 0.011

SITE	SIZE	FOOD	DSTM	AVTL	CUST	SYN SALES	ACT SALES	CS/FT	AS/FT	HH SH	CA$SH	AC$SH
1	481350.	33500.	447850.	8.48	13890.	32996460.	33130240.	68.55	68.83	35.47	35.49	35.22
2	241260.	20860.	220400.	8.39	7039.	16712760.	16829200.	69.27	69.76	17.98	17.98	17.89
3	135390.	26180.	109210.	9.47	4273.	10147200.	10240250.	74.95	75.64	10.91	10.91	10.89
4	117730.	23150.	94580.	8.32	3773.	8958749.	8925700.	76.10	75.81	9.64	9.64	9.49
5	89160.	16650.	72510.	15.49	2625.	6199601.	6711150.	69.53	75.27	6.70	6.67	7.13
6	110060.	25240.	84820.	9.72	3557.	8446771.	8542100.	76.75	77.61	9.08	9.09	9.08
7	74910.	30090.	44820.	11.23	2675.	6350584.	6524100.	84.78	87.09	6.83	6.83	6.94
8	47670.	1260.	46410.	9.55	1328.	3154769.	3167850.	66.18	66.45	3.39	3.39	3.37
TOTAL	1297530.	176930.	1120600.	10.08	39161.	92966860.	94070540.	71.65	72.50	100.00	100.00	100.00

SITE Number	Name
1.	Oshawa Centre
2.	Oshawa Central Business District
3.	Whitby Mall
4.	Mid Town Mall
5.	Bowmanville Central Business District
6.	K-Mart Plaza
7.	Whitby Central Business District
8.	Dundas St. East (Whitby)

SUMMARY SITE INFORMATION

SITE	SIZE	FOOD	OSTM	XS	YS	CUST	CAL SLS	ACT SLS	CS/FT	AS/FT	HH SH	CA$SH	AC$SH
1	481350.	33500.	447850.	7.10	5.30	15022.	36045920.	34657200.	74.89	72.00	38.36	38.77	37.10
2	241260.	20860.	220400.	8.30	5.50	9940.	21049180.	17370720.	87.25	72.00	22.83	22.64	18.59
3	135390.	26180.	109210.	5.10	5.30	3330.	8027666.	9748080.	59.29	72.00	8.50	8.63	10.43
4	117730.	23150.	94580.	7.80	5.30	3921.	9352210.	8476560.	79.44	72.00	10.01	10.06	9.07
5	89160.	16650.	72510.	19.20	3.30	2124.	4550773.	6419520.	51.04	72.00	5.42	4.90	6.87
6	110060.	25240.	84820.	5.60	5.40	2781.	6706137.	7924320.	60.93	72.00	7.10	7.21	8.48
7	74910.	30090.	44820.	3.00	5.50	1876.	4417316.	5393520.	58.97	72.00	4.79	4.75	5.77
8	47670.	1260.	46410.	5.10	5.60	1168.	2817457.	3432240.	59.10	72.00	2.98	3.03	3.67
TOTAL	1297530.	176930.	1120600.			39161.	92966640.	93422160.	71.65	72.00	100.00	100.00	100.00

SITE Number	Name
1.	Oshawa Centre
2.	Oshawa Central Business District
3.	Whitby Mall
4.	Mid Town Mall
5.	Bowmanville Central Business District
6.	K-Mart Plaza
7.	Whitby Central Business District
8.	Dundas St. East (Whitby)

TABLE 3-6 BACKCAST OF RETAIL DISTRIBUTION - (HUFF)
OSHAWA, ONTARIO - 1966
ACTUAL DISTANCE

SUMMARY SITE INFORMATION

SITE	SIZE	FOOD	DSTM	XS	YS	CUST	CAL SLS	ACT SLS	CS/FT	AS/FT	HH SH	CA$SH	AC$SH
1	261760.	29360.	232400.	8.30	5.50	13965.	18433904.	16229120.	70.42	62.00	40.11	39.96	34.87
2	323100.	29000.	294100.	7.10	5.30	14451.	19515584.	20032192.	60.40	62.00	41.51	42.31	43.04
3	89390.	19810.	69580.	19.20	3.30	3199.	3938023.	5542180.	44.05	62.00	9.19	8.54	11.91
4	76370.	30370.	46000.	5.10	5.30	3198.	4239465.	4734940.	55.51	62.00	9.19	9.19	10.17
TOTAL	750620.	108540.	642080.			34814.	46126960.	46538416.	61.45	62.00	100.00	100.00	100.00

SITE

Number	Name
1.	Oshawa Centre
2.	Oshawa Central Business District
3.	Whitby Mall
4.	Mid Town Mall

SUMMARY SITE INFORMATION

SITE	SIZE	FOOD	DSTM	AVTL	CUST	SYN SALES	ACT SALES	CS/FT	AS/FT	HH SH	CA$SH	AC$SH
1	261760.	29360.	232400.	7.38	12043.	15963050.	16011600.	60.98	61.17	34.59	34.61	33.88
2	323100.	29000.	294100.	8.53	14369.	19060190.	19365480.	58.99	59.94	41.27	41.32	40.98
3	89390.	19810.	69580.	15.60	4146.	5461955.	6006000.	61.10	67.19	11.91	11.84	12.71
4	76370.	30370.	46000.	11.18	4256.	5641989.	5870700.	73.88	76.87	12.22	12.23	12.42
TOTAL	750620.	108540.	642080.	10.67	34814.	46127180.	47253770.	61.45	62.95	100.00	100.00	100.00

SITE

Number	Name
1.	Oshawa Centre
2.	Oshawa Central Business District
3.	Whitby Mall
4.	Mid Town Mall

TABLE 3-8 RETAIL DISTRIBUTION - (HUFF)
OSHAWA, ONTARIO - 1976 OPTION 3
ACTUAL DISTANCE

SUMMARY SITE INFORMATION

SITE	SIZE	FOOD	DSTM	XS	YS	CUST	CAL SLS	ACT SLS	CS/FT	AS/FT	HH SH	CA$SH	AC$SH
1	481350.	33500.	447850.	7.10	5.30	13267.	39030240.	34657200.	81.08	72.00	25.65	26.55	27.95
2	241260.	20860.	220400.	8.30	5.50	7190.	21177180.	17370720.	87.73	72.00	14.45	14.41	14.01
3	135390.	26180.	109210.	5.10	5.30	3827.	11307650.	9748080.	83.52	72.00	7.69	7.69	7.85
4	117730.	23150.	94580.	7.80	5.30	3141.	9255050.	8476560.	78.61	72.00	6.31	6.30	6.84
5	89160.	16650.	72510.	19.20	3.30	2519.	7428087.	6419520.	83.31	72.00	5.06	5.05	5.13
6	110060.	25240.	84820.	5.60	5.40	2936.	8661058.	7924320.	78.69	72.00	5.90	5.89	6.39
7	74910.	30090.	44820.	3.00	5.50	2024.	5942780.	5393520.	79.33	72.00	4.07	4.04	4.35
8	47670.	1260.	46410.	5.10	5.60	1343.	3966075.	3432240.	83.20	72.00	2.70	2.70	2.77
9	125000.	20000.	105000.	9.00	8.70	4049.	12139380.	9000000.	97.12	72.00	8.14	8.25	7.25
10	73800.	13000.	60800.	8.40	2.90	2753.	8154171.	5313600.	110.49	72.00	5.53	5.55	4.29
11	145900.	27000.	118900.	8.90	1.90	4303.	12645560.	10504800.	86.67	72.00	8.64	8.60	8.47
12	80000.	12000.	68000.	2.60	5.40	2422.	7250715.	5760000.	90.53	72.00	4.87	4.93	4.65
TOTAL	1722230.	248930.	1473300.			49774.	146957900.	124000500.	85.33	72.00	100.00	100.00	100.00

SITE

Number	Name
1.	Oshawa Centre
2.	Oshawa Central Business District
3.	Whitby Mall
4.	Mid Town Mall
5.	Bowmanville Central Business District
6.	K-Mart Plaza
7.	Whitby Central Business District
8.	Dundas St. E. (Whitby)
9.	Western Auto Parts (S.E. corner Tauriton & Ritson - Oshawa)
10.	Valiant Property Management (S.E. corner Wentworth & Cedar - Oshawa)
11.	F & T Developments (S.W. corner Ritson Rd. S. and Madawaska - Oshawa)
12.	S.W. corner of Dundas W. & Francis St. (Whitby)

SITE	SIZE	FOOD	DSTM	AVTL	CUST	SYN SALES	ACT SALES	CS/FT	AS/FT	HH SH	CA$SH	AC$SH
1	481350.	33500.	447850.	11.37	13081.	38617560.	33130240.	80.23	68.83	26.28	26.27	26.37
2	241260.	20860.	220400.	10.69	6714.	19833610.	16829200.	82.21	69.76	13.49	13.49	13.40
3	135390.	26180.	109210.	11.41	4065.	12001410.	10240250.	88.64	75.64	8.17	8.16	8.15
4	117730.	23150.	94580.	11.57	3540.	10454470.	8925700.	88.80	75.81	7.11	7.11	7.10
5	89160.	16650.	72510.	15.39	2553.	7537625.	6711150.	84.54	75.27	5.13	5.13	5.34
6	110060.	25240.	84820.	12.02	3370.	9951833.	8542100.	90.42	77.61	6.77	6.77	6.80
7	74910.	30090.	44820.	13.02	2549.	7525014.	6524100.	100.45	87.09	5.12	5.12	5.19
8	47670.	1260.	46410.	11.48	1264.	3731532.	3167850.	78.28	66.45	2.54	2.54	2.52
9	125000.	20000.	105000.	9.81	3732.	11039510.	9225000.	88.32	73.80	7.50	7.51	7.34
10	73800.	13000.	60800.	9.58	2241.	6617159.	5512000.	89.66	74.69	4.50	4.50	4.39
11	145900.	27000.	118900.	11.54	4348.	12842310.	10968500.	88.02	75.18	8.74	8.74	8.73
12	80000.	12000.	68000.	12.03	2317.	6853900.	5860000.	85.67	73.25	4.66	4.66	4.66
TOTAL	1722230.	248930.	1473300.	11.66	49774.	147005800.	125636000.	85.36	72.95	100.00	100.00	100.00

SITE

Number	Name
1.	Oshawa Centre
2.	Oshawa Central Business District
3.	Whitby Mall
4.	Mid Town Mall
5.	Bowmanville Central Business District
6.	K-Mart Plaza
7.	Whitby Central Business District
8.	Dundas St. E. (Whitby)
9.	Western Auto Parts (S.E. corner Tauriton & Ritson - Oshawa)
10.	Valiant Property Management (S.E. corner Wentworth & Cedar - Oshawa)
11.	F & T Developments (S.W. corner Ritson Rd. S. and Madawaska - Oshawa)
12.	S.W. corner of Dundas W. & Francis St. (Whitby)

TABLE 3-10 RETAIL DISTRIBUTION - (HUFF)
OSHAWA, ONTARIO - 1981 OPTION 3

SUMMARY SITE INFORMATION

SITE	SIZE	FOOD	DSTM	XS	YS	CUST	CAL SLS	ACT SLS	CS/FT	AS/FT	HH SH	CA$SH	AC$SH
1	481350.	33500.	447850.	7.10	5.30	16384.	56558410.	34657200.	117.50	72.00	25.78	25.88	23.72
2	241260.	20860.	220400.	8.30	5.50	9484.	31888670.	17370720.	132.18	72.00	14.92	14.59	11.89
3	135390.	26180.	109210.	5.10	5.30	4159.	14552410.	9748080.	107.49	72.00	6.54	6.66	6.67
4	117730.	23150.	94580.	7.80	5.30	4144.	14186980.	8476560.	120.50	72.00	6.52	6.49	5.80
5	89160.	16650.	72510.	19.20	3.30	2140.	6643125.	6419520.	74.51	72.00	3.37	3.04	4.39
6	110060.	25240.	84820.	5.60	5.40	3315.	11572730.	7924320.	105.15	72.00	5.22	5.30	5.42
7	74910.	30090.	44820.	3.00	5.50	2295.	7912556.	5393520.	105.63	72.00	3.61	3.62	3.69
8	47670.	46410.	1260.	5.10	5.60	1445.	5054043.	3432240.	106.02	72.00	2.27	2.31	2.35
9	125000.	105000.	20000.	9.00	8.70	3898.	13691920.	9000000.	109.54	72.00	6.13	6.27	6.16
10	73800.	60800.	13000.	8.40	2.90	2268.	7816912.	5313600.	105.92	72.00	3.57	3.58	3.64
11	145900.	118900.	27000.	8.90	1.90	3717.	12755070.	10504800.	87.42	72.00	5.85	5.84	7.19
12	80000.	68000.	12000.	2.60	5.40	2404.	8363917.	5760000.	104.55	72.00	3.78	3.83	3.94
13	107000.	92000.	15000.	12.10	5.30	2799.	9710954.	7704000.	90.76	72.00	4.40	4.44	5.27
14	200000.	165000.	35000.	3.50	7.10	5112.	17829180.	14400000.	89.15	72.00	8.04	8.16	9.86
TOTAL	2029230.	831780.	1197450.			63563.	218536800.	146104500.	107.69	72.00	100.00	100.00	100.00

SITE

Number	Name
1.	Oshawa Centre
2.	Oshawa Central Business District
3.	Whitby Mall
4.	Mid Town Mall
5.	Bowmanville Central Business District
6.	K-Mart Plaza
7.	Whitby Central Business District
8.	Dundas St. E. (Whitby)
9.	Western Auto Parts (S.E. corner Tauriton & Ritson - Oshawa)
10.	Valiant Property Management (S.E. corner Wentworth & Cedar - Oshawa)
11.	F & T Developments (S.W. corner Ritson Rd. S. & Madawaska - Oshawa)
12.	S.W. corner of Dundas W. & Francis St. (Whitby)
13.	Riznek Construction (Darlington Twp.)
14.	Bradley Farm (Rossland & Garden - Whitby)

SUMMARY SITE INFORMATION

SITE	SIZE	FOOD	DSTM	AVTL	CUST	SYN SALES	ACT SALES	CS/FT	AS/FT	HH SH	CA$SH	AC$SH
1	481350.	33500.	447850.	10.83	14186.	48752112.	33130240.	101.28	68.83	22.32	22.31	22.33
2	241260.	20860.	220400.	10.72	7221.	24821680.	16829200.	102.88	69.76	11.36	11.36	11.34
3	135390.	26180.	109210.	11.09	4398.	15116900.	10240250.	111.65	75.64	6.92	6.92	6.90
4	117730.	23150.	94580.	11.08	3837.	13191511.	8925700.	112.05	75.81	6.04	6.04	6.02
5	89160.	16650.	72510.	15.55	2748.	9442393.	6711150.	105.90	75.27	4.32	4.32	4.52
6	110060.	25240.	84820.	11.59	3651.	12551165.	8542100.	114.04	77.61	5.74	5.74	5.76
7	74910.	30090.	44820.	12.76	2757.	9472565.	6524100.	126.45	87.09	4.34	4.33	4.40
8	47670.	1260.	46410.	11.16	1367.	4700291.	3167850.	98.60	66.45	2.15	2.15	2.14
9	125000.	20000.	105000.	9.64	4031.	13876493.	9225000.	111.01	73.80	6.34	6.35	6.22
10	73800.	13000.	60800.	9.91	2408.	8273698.	5512000.	112.11	74.69	3.79	3.79	3.72
11	145900.	27000.	118900.	11.86	4673.	16058301.	10968500.	110.06	75.18	7.35	7.35	7.39
12	80000.	12000.	68000.	11.77	2505.	8624553.	5860000.	107.81	73.25	3.94	3.95	3.95
13	107000.	15000.	92000.	11.41	3338.	11467232.	7780000.	107.17	72.71	5.25	5.25	5.24
14	200000.	35000.	165000.	10.50	6443.	22188000.	14925000.	110.94	74.63	10.14	10.15	10.06
TOTAL	2029230.	298930.	1730300.	11.42	63563.	218536816.	148341024.	107.69	73.10	100.00	100.00	100.00

SITE Number	Name
1.	Oshawa Centre
2.	Oshawa Central Business District
3.	Whitby Mall
4.	Mid Town Mall
5.	Bowmanville Central Business District
6.	K-Mart Plaza
7.	Whitby Central Business District
8.	Dundas St. E. (Whitby)
9.	Western Auto Parts (S.E. corner Tauriton & Ritson - Oshawa)
10.	Valiant Property Management (S.E. corner Wentworth & Cedar - Oshawa)
11.	F & T Developments (S.W. corner Ritson Rd. S. & Madawaska - Oshawa)
12.	S.W. corner of Dundas W. & Francis St. (Whitby)
13.	Riznek Construction (Darlington Twp.)
14.	Bradley Farm (Rossland & Garden - Whitby)

TABLE 3-12 EXISTING RETAIL DISTRIBUTION - (HUFF)
OSHAWA, ONTARIO - 1971
NEIGHBOURHOOD SUMMARY

NBHD 1

CT	XN	YN	ALA1	ALA2	ALA3	R	BF
138.00	0.80	4.90	0.7500	0.0	0.7500	0.0	2415.00

SITE	DIST	CUST	EXPEND	SIZE	XS	YS	HSHARE
1	12.20	51.	122710.	481350.	7.10	5.30	0.37
2	15.30	21.	51899.	241260.	8.30	5.50	0.16
3	10.20	16.	39475.	135390.	5.10	5.30	0.12
4	13.90	11.	27215.	117730.	7.80	5.30	0.08
5	24.60	6.	13433.	89160.	19.20	3.30	0.04
6	10.80	13.	30743.	110060.	5.60	5.40	0.09
7	5.70	14.	33793.	74910.	3.00	5.50	0.10
8	10.10	6.	14002.	47670.	5.10	5.60	0.04
TOTAL		138.	333270.				1.00

SITE

Number	Name
1.	Oshawa Centre
2.	Oshawa Central Business District
3.	Whitby Mall
4.	Mid Town Mall
5.	Bowmanville Central Business District
6.	K-Mart Plaza
7.	Whitby Central Business District
8.	Dundas St. East (Whitby)

ZONAL RETAIL SPENDING

1	333270.	58	225665.
2	622883.	59	374874.
3	118305.	60	1116594.
4	13636.	61	144314.
5	1946490.	62	446250.
6	315208.	63	209322.
7	803950.	64	104884.
8	403956.	65	352755.
9	145470.	66	57816.
10	133536.	67	350819.
11	263952.		
12	3387440.		
13	871024.		
14	2939628.		
15	1535523.		
16	3242401.		
17	82940.		
18	268522.		
19	939922.		
20	1166074.		
21	2221114.		
22	5836592.		
23	2850718.		
24	3180190.		
25	2273590.		
26	3144302.		
27	3418252.		
28	3111372.		
29	629802.		
30	1138805.		
31	473184.		
32	2072112.		
33	1601238.		
34	1457946.		
35	1391715.		
36	5701996.		
37	2807538.		
38	4940285.		
39	2175620.		
40	4204200.		
41	78302.		
42	337820.		
43	214896.		
44	4145877.		
45	5231800.		
46	353338.		
47	794476.		
48	645325.		
49	293920.		
50	835485.		
51	247058.		
52	311353.		
53	819072.		
54	309514.		
55	183352.		
56	223613.		
57	394176.		

TABLE 3-14 EXISTING RETAIL DISTRIBUTION - (CULLEN)
OSHAWA, ONTARIO - 1971
CUSTOMER FLOWS (ZONES TO CENTRES)

	1	2	3	4	5	6	7	8
1	49.	24.	15.	13.	9.	13.	10.	5.
2	99.	51.	31.	27.	18.	26.	21.	10.
3	19.	10.	6.	5.	4.	5.	4.	2.
4	3.	1.	1.	1.	0.	1.	0.	0.
5	285.	148.	88.	77.	54.	72.	55.	27.
6	44.	23.	14.	12.	8.	11.	8.	4.
7	123.	65.	37.	34.	26.	31.	23.	12.
8	69.	35.	21.	19.	14.	18.	13.	7.
9	27.	14.	8.	7.	6.	7.	5.	3.
10	27.	14.	8.	7.	6.	7.	5.	3.
11	49.	25.	15.	13.	12.	12.	9.	5.
12	455.	237.	141.	123.	86.	116.	88.	44.
13	109.	54.	35.	29.	19.	29.	23.	11.
14	476.	110.	152.	128.	89.	126.	102.	47.
15	207.	103.	68.	55.	37.	56.	41.	21.
16	502.	264.	156.	137.	95.	129.	98.	48.
17	15.	8.	5.	4.	4.	4.	3.	1.
18	42.	22.	13.	11.	10.	11.	8.	4.
19	162.	84.	50.	44.	38.	41.	31.	16.
20	210.	105.	68.	56.	38.	57.	46.	21.
21	299.	148.	89.	79.	52.	76.	55.	28.
22	930.	468.	276.	250.	165.	232.	172.	85.
23	467.	241.	144.	126.	89.	119.	90.	45.
24	391.	205.	118.	107.	77.	97.	74.	37.
25	420.	216.	130.	113.	102.	107.	80.	40.
26	533.	279.	160.	146.	97.	133.	100.	49.

31	86.	44.	27.	23.	21.	22.	17.	8.
32	308.	153.	100.	82.	56.	83.	67.	31.
33	218.	108.	71.	58.	39.	59.	44.	22.
34	194.	97.	64.	52.	34.	53.	39.	20.
35	183.	91.	55.	49.	31.	47.	34.	17.
36	788.	393.	237.	210.	135.	201.	145.	74.
37	526.	276.	156.	145.	93.	132.	96.	49.
38	698.	366.	207.	192.	126.	175.	127.	65.
39	256.	134.	77.	70.	50.	64.	48.	24.
40	666.	377.	214.	198.	127.	181.	131.	67.
41	12.	6.	4.	3.	2.	3.	3.	1.
42	50.	25.	16.	13.	9.	13.	10.	5.
43	26.	13.	8.	7.	5.	7.	5.	3.
44	563.	294.	171.	153.	99.	142.	107.	53.
45	656.	347.	199.	178.	118.	165.	124.	62.
46	49.	26.	15.	13.	9.	12.	9.	5.
47	117.	61.	35.	32.	24.	29.	22.	11.
48	109.	56.	34.	30.	23.	28.	21.	10.
49	56.	29.	17.	15.	14.	14.	11.	5.
50	115.	60.	36.	32.	21.	30.	22.	11.
51	35.	17.	11.	9.	6.	9.	7.	3.
52	47.	23.	15.	13.	8.	12.	9.	5.
53	111.	58.	35.	30.	20.	29.	22.	11.
54	43.	22.	13.	12.	8.	11.	8.	4.
55	30.	16.	9.	8.	6.	8.	6.	3.
56	36.	19.	11.	10.	8.	9.	7.	3.
57	66.	35.	21.	18.	16.	17.	13.	6.
58	42.	22.	13.	11.	10.	11.	8.	4.

TABLE 3-14 - CONTINUED

59	46.	23.	15.	12.	8.	12.	9.	5.
60	189.	94.	60.	50.	33.	50.	39.	19.
61	21.	10.	7.	6.	4.	6.	4.	2.
62	73.	38.	23.	20.	13.	19.	14.	7.
63	30.	16.	10.	8.	6.	8.	6.	3.
64	18.	9.	6.	5.	4.	5.	4.	2.
65	67.	35.	21.	18.	16.	18.	13.	7.
66	11.	6.	4.	3.	3.	3.	2.	1.
67	57.	28.	18.	15.	10.	15.	11.	6.

1	117738.	57998.	37420.	31337.	20976.	31037.	25107.	11657.
2	218974.	111242.	69214.	58927.	40498.	57031.	45578.	21419.
3	41421.	21252.	13443.	10892.	7737.	11077.	8323.	4160.
4	4924.	2437.	1476.	1311.	891.	1217.	923.	457.
5	688077.	357722.	212290.	185369.	129517.	174922.	132898.	65696.
6	111371.	57330.	34399.	30037.	21572.	28344.	21511.	10645.
7	283493.	148524.	85374.	77815.	58592.	70346.	53387.	26420.
8	141897.	73044.	43827.	38650.	29456.	36113.	27407.	13563.
9	50792.	26174.	15688.	13850.	11375.	12926.	9810.	4855.
10	46596.	24013.	14392.	12567.	10656.	11859.	9000.	4454.
11	91791.	47303.	28351.	24756.	21888.	23361.	17729.	8774.
12	1197141.	622378.	369756.	322511.	225337.	304670.	231221.	114427.
13	307639.	151545.	97991.	81882.	54808.	81099.	65602.	30459.
14	1136119.	263731.	363480.	305735.	211978.	301482.	243875.	113230.
15	540283.	269091.	176698.	144119.	97320.	145595.	107735.	54682.
16	1139003.	598703.	354908.	310243.	215340.	292436.	221935.	109832.
17	28819.	15098.	8833.	7910.	6745.	7278.	5523.	2733.
18	93507.	48187.	28881.	25219.	21932.	23797.	18060.	8938.
19	327514.	168778.	101158.	88330.	76229.	83352.	63257.	31305.
20	407731.	203073.	132470.	108522.	74256.	109875.	88880.	41267.
21	804586.	398092.	240442.	211574.	140687.	203419.	147085.	75252.
22	2105890.	1059285.	623809.	566082.	373531.	524860.	390089.	193048.
23	1008848.	520464.	311598.	271187.	191153.	256186.	194853.	96429.
24	1125334.	589569.	338894.	308889.	220620.	279856.	211922.	105107.
25	789348.	406776.	243802.	212885.	192407.	201552.	151122.	75698.
26	1119030.	586266.	335516.	306147.	203573.	280131.	209809.	103831.
27	1218752.	622559.	367430.	334531.	225403.	306103.	229767.	113707.
28	1094534.	574064.	338064.	298131.	212001.	278557.	211403.	104619.

TABLE 3-15 - CONTINUED

29	218994.	114732.	67195.	60177.	50524.	55367.	42019.	20794.
30	395409.	203767.	122128.	106641.	96065.	100631.	76371.	37795.
31	164358.	84699.	50765.	44181.	39191.	41829.	32451.	15710.
32	724841.	361011.	235498.	192925.	132008.	195330.	157140.	73361.
33	563647.	280728.	183127.	150021.	99757.	151892.	115021.	57047.
34	512918.	255462.	168303.	136519.	90779.	139596.	101941.	52429.
35	502519.	250282.	151167.	133751.	86335.	127890.	92473.	47298.
36	2058871.	1025431.	619345.	547991.	353725.	523979.	378870.	193786.
37	1003444.	525709.	297896.	275432.	177594.	252026.	182231.	93208.
38	1763479.	923897.	523530.	484051.	318350.	442917.	320258.	163807.
39	770534.	403686.	232045.	211501.	149738.	191200.	145106.	71810.
40	1429119.	808653.	458227.	423672.	273177.	387669.	280310.	143374.
41	27718.	13639.	8848.	7377.	4836.	7339.	5788.	2756.
42	119888.	59383.	38272.	31909.	20848.	31744.	23854.	11922.
43	76941.	38321.	23817.	20479.	13321.	19754.	14844.	7419.
44	1475643.	770550.	447824.	401495.	260306.	371440.	279117.	139504.
45	1856340.	980064.	563356.	503412.	334745.	467267.	351125.	175494.
46	125152.	65280.	37981.	34127.	23792.	31503.	23672.	11832.
47	280685.	147053.	84528.	77044.	56500.	69649.	52858.	26159.
48	226789.	115975.	69586.	62250.	48338.	57338.	43515.	21535.
49	102440.	52501.	31605.	26878.	24888.	26042.	19786.	9781.
50	294789.	153933.	91351.	80738.	53510.	75770.	56937.	28457.
51	87341.	43262.	27882.	23247.	15255.	23126.	18260.	8686.
52	110495.	54731.	35273.	29409.	19215.	29257.	21985.	10988.
53	288880.	150847.	89717.	79032.	52437.	74414.	55796.	27948.
54	108209.	56878.	33903.	29636.	21075.	28120.	21131.	10561.
55	63764.	33517.	19978.	17464.	13383.	16571.	12452.	6224.
56	77393.	40681.	24248.	21197.	17314.	20112.	15113.	7554.

61	51045.	25284.	16295.	13586.	8877.	13516.	10636.	5076.
62	156061.	81492.	49929.	42695.	28328.	41413.	30779.	15554.
63	73310.	38155.	22994.	19859.	14436.	19072.	14332.	7163.
64	36581.	19039.	11474.	9920.	7627.	9517.	7151.	3574.
65	122078.	63537.	38291.	33106.	28165.	31760.	23892.	11928.
66	19908.	10464.	6224.	5452.	4779.	5162.	3888.	1939.
67	124777.	61805.	39614.	33211.	21579.	32857.	24636.	12340.

TABLE 3-16 EXISTING RETAIL DISTRIBUTION - (HUFF)
BELLEVILLE, ONTARIO - 1966
LAMBDA (λ) = 0.88

SUMMARY SITE INFORMATION

SITE	SIZE	FOOD	DSTM	XS	YS	CUST	CAL SLS	ACT SLS	CS/FT	AS/FT	HH SH	CA$SH	AC$SH
1	344800.	61200.	283600.	0.00	0.00	54115.	23007920.	21722400.	66.73	63.00	45.07	46.53	43.92
2	98600.	41600.	57000.	0.00	0.00	14827.	6285025.	5211800.	63.74	63.00	12.35	12.71	12.56
3	71000.	18000.	53000.	0.00	0.00	8534.	3487770.	4473000.	49.12	63.00	7.11	7.05	9.04
4	152900.	41600.	111300.	0.00	0.00	25888.	10139330.	9632700.	66.31	63.00	21.56	20.50	19.48
5	49400.	9500.	39800.	0.00	0.00	7924.	3105267.	3112200.	62.86	63.00	6.60	6.28	6.29
6	68300.	16300.	51500.	0.00	0.00	8769.	3427155.	4302900.	50.18	63.00	7.30	6.93	8.70
TOTAL	785000.	188800.	596200.			120056.	49452440.	49454960.	63.00	63.00	100.00	100.00	100.00

SITE Number	Name
1.	Belleville Central Business District
2.	Belleville Plaza
3.	Towers
4.	Trenton
5.	Picton
6.	Napanee

SITE	SIZE	FOOD	DSTM	AVTL	CUST	SYN SALES	ACT SALES	CS/FT	AS/FT	HH SH	CA$SH	AC$SH
1	344800.	61200.	283600.	46.69	48652.	20689920.	20300000.	60.01	58.87	40.52	41.84	41.09
2	98600.	41600.	57000.	49.56	16546.	7016658.	7010000.	71.16	71.10	13.78	14.19	14.19
3	71000.	18000.	53000.	52.06	11534.	4823254.	5160000.	67.93	72.68	9.61	9.75	10.45
4	152900.	41600.	111300.	34.55	24427.	9555875.	9725000.	62.50	63.60	20.35	19.32	19.69
5	49400.	9600.	39800.	27.01	8922.	3487932.	2950000.	70.61	59.72	7.43	7.05	5.97
6	68300.	16800.	51500.	29.62	9975.	3878850.	4255000.	56.79	62.30	8.31	7.84	8.61
TOTAL	785000.	188800.	596200.	39.92	120056.	49452460.	49399980.	63.00	62.93	100.00	100.00	100.00

SITE

Number	Name
1.	Belleville Central Business District
2.	Belleville Plaza
3.	Towers
4.	Trenton
5.	Picton
6.	Napanee

TABLE 3-18 FORECAST OF RETAIL DISTRIBUTION - (HUFF)
BELLEVILLE, ONTARIO - 1971

SUMMARY SITE INFORMATION

SITE	SIZE	FOOD	DSTM	XS	YS	CUST	CAL SLS	ACT SLS	CS/FT	AS/FT	HH SH	CA$SH	AC$SH
1	342000.	61200.	280800.	0.00	0.00	46149.	23159200.	21546000.	67.72	63.00	36.55	37.75	35.29
2	98600.	41600.	57000.	0.00	0.00	12832.	6425090.	6211800.	65.16	63.00	10.16	10.47	10.18
3	71000.	18000.	53000.	0.00	0.00	7401.	3564095.	4473000.	50.20	63.00	5.86	5.81	7.33
4	152900.	41600.	111300.	0.00	0.00	23516.	10825910.	9632700.	70.80	63.00	18.62	17.65	15.78
5	49400.	9600.	39800.	0.00	0.00	7005.	3230331.	3112200.	65.39	63.00	5.55	5.27	5.10
6	68300.	16800.	51500.	0.00	0.00	7973.	3671877.	4302900.	53.76	63.00	6.31	5.99	7.05
7	186800.	40800.	146000.	0.00	0.00	21393.	10464970.	11768400.	56.02	63.00	16.94	17.06	19.28
TOTAL	969000.	229600.	739400.			126268.	61341420.	61046960.	63.30	63.00	100.00	100.00	100.00

SITE

Number	Name
1.	Belleville Central Business District
2.	Belleville Plaza
3.	Towers
4.	Trenton
5.	Picton
6.	Napanee
7.	Quinte Mall

SITE	SIZE	FOOD	DSTM	AVTL	CUST	SYN SALES	ACT SALES	CS/FT	AS/FT	HH SH	CA$SH	AC$SH
1	342000.	61200.	280800.	47.79	39316.	19686190.	20160000.	57.56	58.95	31.14	32.09	32.62
2	98600.	41600.	57000.	50.76	13492.	6736503.	7010000.	68.32	71.10	10.69	10.98	11.34
3	71000.	18000.	53000.	52.44	8290.	4076234.	4450000.	57.41	62.68	6.57	6.65	7.20
4	152900.	41600.	111300.	32.69	21860.	10025530.	9725000.	65.57	63.60	17.31	16.34	15.74
5	49400.	9600.	39800.	27.03	8024.	3691475.	2950000.	74.73	59.72	6.35	6.02	4.77
6	68300.	16800.	51500.	28.11	9788.	4489289.	4255000.	65.73	62.30	7.75	7.32	6.89
7	186800.	40800.	146000.	52.04	25497.	12636270.	13248000.	67.65	70.92	20.19	20.60	21.44
TOTAL	969000.	229600.	739400.	41.55	126268.	61341470.	61797980.	63.30	63.78	100.00	100.00	100.00

SITE

Number	Name
1.	Belleville Central Business District
2.	Belleville Plaza
3.	Towers
4.	Trenton
5.	Picton
6.	Napanee
7.	Quinte Mall

TABLE 3-20 RETAIL DISTRIBUTION - (HUFF)
BELLEVILLE, ONTARIO - 1976 OPTION 1

SUMMARY SITE INFORMATION

SITE	SIZE	FOOD	DSTM	XS	YS	CUST	CAL SLS	ACT SLS	CS/FT	AS/FT	HH SH	CA$SH	AC$SH
1	342000.	61200.	280800.	0.00	0.00	41184.	24051500.	21546000.	70.33	63.00	30.69	31.72	29.44
2	168600.	41600.	127000.	0.00	0.00	19187.	11149460.	10621800.	66.13	63.00	14.30	14.71	14.52
3	71000.	18000.	53000.	0.00	0.00	6592.	3685340.	4473000.	51.91	63.00	4.91	4.86	6.11
4	152900.	41600.	111300.	0.00	0.00	21414.	11354250.	9632700.	74.26	63.00	15.96	14.98	13.16
5	49400.	9600.	39800.	0.00	0.00	6332.	3362180.	3112200.	68.06	63.00	4.72	4.43	4.25
6	68300.	16800.	51500.	0.00	0.00	7431.	3944514.	4302900.	57.75	63.00	5.54	5.20	5.88
7	309300.	40800.	268500.	0.00	0.00	32043.	18267660.	19485880.	59.06	63.00	23.88	24.10	26.63
TOTAL	1161500.	229600.	931900.			134184.	75814880.	73174440.	65.27	63.00	100.00	100.00	100.00

SITE

Number	Name
1.	Belleville Central Business District
2.	Belleville Plaza
3.	Towers
4.	Trenton
5.	Picton
6.	Napanee
7.	Quinte Mall

SUMMARY SITE INFORMATION

SITE	SIZE	FOOD	DSTM	AVTL	CUST	SYN SALES	ACT SALES	CS/FT	AS/FT	HH SH	CA$SH	AC$SH
1	342000.	61200.	280800.	46.84	34842.	20282680.	20160000.	59.31	58.95	25.97	26.75	27.12
2	168600.	41600.	127000.	49.97	20471.	11877780.	12196000.	70.45	72.34	15.26	15.67	16.41
3	71000.	18000.	53000.	51.42	7389.	4216250.	4450000.	59.38	62.68	5.51	5.56	5.99
4	152900.	41600.	111300.	31.71	19984.	10548540.	9725000.	68.99	63.60	14.89	13.91	13.08
5	49400.	9600.	39800.	26.83	7230.	3827846.	2950000.	77.49	59.72	5.39	5.05	3.97
6	68300.	16800.	51500.	26.39	9578.	5062693.	4255000.	74.12	62.30	7.14	6.68	5.72
7	309300.	40800.	268500.	50.64	34690.	19999130.	20598000.	64.66	66.60	25.85	26.38	27.71
TOTAL	1161500.	229600.	931900.	40.54	134184.	75814890.	74333980.	65.27	64.00	100.00	100.00	100.00

SITE

Number	Name
1.	Belleville Central Business District
2.	Belleville Plaza
3.	Towers
4.	Trenton
5.	Picton
6.	Napanee
7.	Quinte Mall

TABLE 3-22 RETAIL DISTRIBUTION - (HUFF)
BELLEVILLE, ONTARIO - 1981 OPTION 6

SUMMARY SITE INFORMATION

SITE	SIZE	FOOD	DSTM	XS	YS	CUST	CAL SLS	ACT SLS	CS/FT	AS/FT	HH SH	CA$SH	AC$SH
1	341200.	61200.	280000.	0.00	0.00	38234.	24691290.	21495600.	72.37	63.00	27.00	28.13	24.69
2	168600.	41600.	127000.	0.00	0.00	17901.	11501990.	10621800.	68.22	63.00	12.64	13.11	12.20
3	71000.	18000.	53000.	0.00	0.00	5991.	3700740.	4473000.	52.12	63.00	4.23	4.22	5.14
4	152900.	41600.	111300.	0.00	0.00	18097.	10504090.	9632700.	68.70	63.00	12.78	11.97	11.06
5	49400.	9600.	39800.	0.00	0.00	5765.	3342307.	3112200.	67.66	63.00	4.07	3.81	3.57
6	68300.	16800.	51500.	0.00	0.00	7067.	4000169.	4302900.	58.57	63.00	4.99	4.56	4.94
7	309300.	40800.	268500.	0.00	0.00	30149.	19058970.	19485880.	61.62	63.00	21.29	21.72	22.38
8	100000.	20000.	80000.	0.00	0.00	8704.	5062352.	6300000.	50.62	63.00	6.15	5.77	7.24
9	121400.	22000.	99400.	0.00	0.00	9676.	5903288.	7648200.	48.63	63.00	6.83	6.73	8.78
TOTAL	1382100.	271600.	1110500.			141584.	87765160.	87072240.	63.50	63.00	100.00	100.00	100.00

SITE Number	Name
1.	Belleville Central Business District
2.	Belleville Plaza
3.	Towers
4.	Trenton
5.	Picton
6.	Napanee
7.	Quinte Mall
8.	Trenton New Centre
9.	Leasehold Proposed Plaza

SITE	SIZE	FOOD	DSTM	AVTL	CUST	SYN SALES	ACT SALES	CS/FT	AS/FT	HH SH	CA$SH	AC$SH
1	341200.	61200.	280000.	44.64	31472.	20271660.	20120000.	59.41	58.97	22.23	23.10	22.44
2	168600.	41600.	127000.	47.92	18650.	11951720.	12196000.	70.89	72.34	13.17	13.62	13.60
3	71000.	18000.	53000.	49.90	6501.	4111589.	4450000.	57.91	62.68	4.59	4.68	4.96
4	152900.	41600.	111300.	34.70	14866.	8620668.	9725000.	56.38	63.60	10.50	9.82	10.84
5	49400.	9600.	39800.	26.73	6636.	3830567.	2950000.	77.54	59.72	4.69	4.36	3.29
6	68300.	16800.	51500.	25.24	9791.	5463686.	4255000.	80.00	62.30	6.92	6.23	4.74
7	309300.	40800.	268500.	48.17	31381.	20029690.	20596000.	64.76	66.60	22.16	22.82	22.97
8	100000.	20000.	80000.	38.36	10569.	6129133.	7000000.	61.29	70.00	7.47	6.98	7.81
9	121400.	22000.	99400.	51.53	11717.	7356516.	8384000.	60.60	69.06	8.28	8.38	9.35
TOTAL	1382100.	271600.	1110500.	40.80	141584.	87765180.	89677980.	63.50	64.89	100.00	100.00	100.00

SITE

Number	Name
1.	Belleville Central Business District
2.	Belleville Plaza
3.	Towers
4.	Trenton
5.	Picton
6.	Napaneee
7.	Quinte Mall
8.	Trenton New Centre
9.	Leasehold Proposed Plaza

TABLE 3-24 EXISTING RETAIL DISTRIBUTION - (HUFF)
BELLEVILLE, ONTARIO - 1971
NEIGHBOURHOOD SUMMARY

NBHD 1

CT	XN	YN	ALA1	ALA2	ALA3	R	BF
996.00	0.0	0.0	0.8800	0.0	0.8800	0.0	503.00

SITE	DIST	CUST	EXPEND	SIZE	XS	YS	HSHARE
1	10.00	471.	265314.	342000.	0.0	0.0	0.47
2	19.81	74.	41913.	98600.	0.0	0.0	0.07
3	3.75	232.	130571.	71000.	0.0	0.0	0.23
4	58.41	45.	25098.	152900.	0.0	0.0	0.04
5	112.03	9.	4571.	49400.	0.0	0.0	0.01
6	156.05	8.	4722.	68300.	0.0	0.0	0.01
7	17.50	157.	88560.	186800.	0.0	0.0	0.16
TOTAL		996.	560749.				1.00

SITE

Number	Name
1.	Belleville Central Business District
2.	Belleville Plaza
3.	Towers
4.	Trenton
5.	Picton
6.	Napanee
7.	Quinte Mall

ZONAL RETAIL SPENDING

1	452670.
2	229890.
3	460728.
4	157842.
5	226572.
6	245532.
7	235578.
8	194340.
9	359292.
10	151680.
11	429918.
12	506232.
13	365454.
14	368298.
15	170640.
16	177276.
17	309522.
18	398634.
19	298146.
20	501492.
21	416646.
22	164478.
23	657912.
24	391998.
25	108072.
26	507180.
27	606720.
28	337014.
29	565956.
30	236526.
31	798690.
32	302886.
33	406218.
34	246480.
35	233682.
36	434658.
37	111864.
38	228468.
39	653172.
40	302412.
41	462150.
42	639900.
43	529932.
44	37446.
45	5850390.
46	1885650.
47	5384730.
48	4028391.
49	3550170.
50	1874730.
51	2003430.
52	1682460.
53	1969890.
54	1632540.
55	1781308.
56	939348.
57	1249360.

TABLE 3-26 EXISTING RETAIL DISTRIBUTION - (CULLEN)
BELLEVILLE, ONTARIO - 1966
CUSTOMER FLOWS (ZONES TO CENTRES)

	1	2	3	4	5	6
1	560.	148.	178.	64.	4.	2.
2	296.	79.	79.	29.	2.	1.
3	621.	163.	134.	48.	4.	2.
4	217.	57.	42.	15.	1.	1.
5	305.	89.	59.	22.	2.	1.
6	327.	107.	61.	20.	2.	1.
7	299.	121.	54.	20.	2.	1.
8	240.	109.	43.	16.	1.	1.
9	436.	211.	77.	28.	3.	2.
10	209.	58.	38.	14.	1.	1.
11	585.	174.	105.	38.	3.	2.
12	671.	228.	120.	44.	4.	2.
13	465.	189.	83.	30.	3.	2.
14	500.	130.	104.	38.	3.	1.
15	237.	62.	44.	16.	1.	1.
16	247.	66.	43.	16.	1.	1.
17	423.	126.	74.	27.	2.	1.
18	530.	180.	93.	34.	3.	2.
19	379.	154.	69.	24.	2.	2.
20	619.	284.	109.	40.	3.	3.
21	509.	242.	90.	33.	3.	3.
22	219.	58.	51.	18.	1.	1.
23	910.	239.	189.	43.	5.	2.
24	545.	147.	106.	25.	3.	1.
25	152.	42.	27.	7.	1.	0.
26	701.	209.	122.	32.	4.	1.

31	1102.	296.	222.	57.	6.	2.
32	418.	121.	76.	21.	2.	1.
33	555.	166.	102.	31.	3.	1.
34	336.	105.	60.	18.	2.	1.
35	314.	104.	56.	17.	2.	1.
36	579.	202.	101.	30.	3.	1.
37	147.	54.	26.	8.	1.	0.
38	297.	116.	52.	15.	2.	1.
39	874.	242.	195.	59.	5.	2.
40	407.	115.	85.	27.	2.	1.
41	622.	184.	122.	42.	3.	2.
42	860.	268.	160.	55.	4.	2.
43	701.	241.	126.	45.	4.	2.
44	49.	18.	9.	3.	0.	0.
45	5200.	2118.	1479.	1172.	4831.	202.
46	843.	365.	197.	125.	3200.	105.
47	2686.	862.	1051.	9168.	33.	7.
48	2081.	548.	797.	7169.	28.	5.
49	3694.	955.	1336.	3078.	30.	10.
50	2583.	781.	603.	798.	16.	26.
51	2721.	863.	610.	856.	19.	68.
52	2339.	881.	434.	296.	34.	330.
53	3061.	1076.	568.	294.	25.	29.
54	1845.	881.	323.	120.	168.	848.
55	249.	119.	44.	16.	56.	4106.
56	251.	120.	44.	16.	41.	1948.
57	380.	182.	73.	29.	326.	2231.

TABLE 3-27 EXISTING RETAIL DISTRIBUTION - (CULLEN)
BELLEVILLE, ONTARIO - 1966
CASH FLOWS (ZONES TO CENTRES)

	1	2	3	4	5	6
1	265482.	70098.	84269.	30221.	1884.	717.
2	140077.	37332.	37472.	13642.	987.	381.
3	294334.	77413.	63430.	22960.	1807.	784.
4	102908.	27172.	19741.	7159.	586.	276.
5	144794.	42309.	27935.	10207.	891.	437.
6	155138.	50848.	28775.	9322.	928.	522.
7	141630.	57501.	25637.	9384.	833.	593.
8	113935.	51576.	20274.	7381.	653.	522.
9	206872.	100021.	36668.	13397.	1187.	1147.
10	99161.	27333.	17875.	6496.	547.	269.
11	277482.	82481.	49569.	18008.	1543.	836.
12	317992.	107989.	56686.	20674.	1798.	1094.
13	220194.	89722.	39111.	14264.	1254.	909.
14	237155.	61796.	49519.	17823.	1382.	624.
15	112146.	29222.	20838.	7530.	608.	295.
16	117055.	31498.	20407.	7387.	611.	318.
17	200542.	59593.	35015.	12702.	1069.	601.
18	251214.	85158.	44034.	15997.	1370.	861.
19	179496.	72875.	32541.	11496.	1004.	735.
20	293333.	134838.	51510.	18786.	1643.	1381.
21	241162.	114860.	42438.	15478.	1363.	1345.
22	103678.	27268.	24181.	8476.	599.	275.
23	431383.	113050.	89724.	20485.	2426.	846.
24	258223.	69737.	50195.	11924.	1428.	492.
25	71918.	19675.	12770.	3204.	373.	132.

31	522569.	140323.	105059.	26800.	2834.	1107.
32	198234.	57283.	35873.	10054.	1028.	415.
33	263000.	78600.	48140.	14515.	1364.	599.
34	159153.	49565.	28260.	8333.	825.	344.
35	148755.	49301.	26319.	8195.	774.	338.
36	274445.	95699.	48020.	14452.	1445.	597.
37	69810.	25612.	12193.	3725.	370.	154.
38	140706.	54920.	24568.	7216.	760.	298.
39	414401.	114881.	92391.	28067.	2273.	1159.
40	193139.	54566.	40474.	12671.	1038.	523.
41	294894.	87315.	57756.	19823.	1544.	818.
42	407534.	127185.	76000.	25991.	2117.	1073.
43	332219.	114083.	59885.	21149.	1722.	873.
44	23123.	8354.	4168.	1614.	120.	67.
45	2028018.	825851.	576826.	456961.	1884045.	78694.
46	328905.	142238.	76712.	48795.	1247896.	41103.
47	1047459.	336368.	409751.	3575503.	12859.	2790.
48	788847.	207726.	302159.	2717131.	10471.	2057.
49	1440486.	372540.	521126.	1200370.	11891.	3757.
50	1007519.	304660.	234989.	311289.	6232.	10045.
51	1061010.	336646.	237980.	333783.	7468.	26543.
52	912380.	343603.	169330.	115420.	13135.	128591.
53	1193610.	419480.	221524.	114509.	9561.	11205.
54	719728.	343720.	126159.	46849.	65441.	330645.
55	96593.	46130.	17085.	6364.	21906.	1593231.
56	97463.	46545.	17084.	6344.	16071.	755841.
57	147603.	70490.	28230.	11133.	126433.	865472.

4 General Conclusions and Areas for Further Research

The applications in the two case-study municipalities have demonstrated the power of the two versions of the retail model to help the urban and regional planner arrive at public policies on shopping centres and at shopping centre decisions.

The Cullen version of the model appears to have somewhat superior operating characteristics. The predictive capability of both versions of the retail model appears to be at least equal to or better than that obtained by conventional methods.

Because retail models and trade area analysis rely on similar data bases and face the same problems of estimation, the demonstrated predictive ability of the retail model gives it a powerful advantage.

In effect, the research has confirmed the postulations that retail models can evaluate a wide range of alternative arrangements for providing retail shopping facilities under varying assumptions with a high degree of reliability. Generally, data is available to operate the models and perceptive measures of forecasted results are obtained.

Other less dramatic but important conclusions about retail models were reached.

1. The problems of establishing a sound data base are quite clear. Any municipal or regional planning study is only as sound as the quality of the information on which it is based, and the application of the retail model is no exception.

   High-quality data for past and current years are required whether a site evaluation of the step-by-step type is to be

employed or a retail model is to be used.

Subsequent applications of the retail model in real-world planning studies in Ontario have substantiated the notion that it is essential to do a trade area analysis as a preliminary step in approaching a model application. A survey of consumer shopping is particularly important in this regard.

Household Incomes. Finding sources of income information for small statistical areas was a serious problem which was only partially overcome in both case study areas, although greater success was achieved in Oshawa than in Belleville.

Income information will improve only in part once 1971 census information from Statistics Canada becomes available. The 1971 census will provide average household income information for statistical areas for the principal urban centres based on a one-third sample. Estimates for rural areas will remain difficult. Moreover, it will still be necessary to derive estimates for intercensal years.

Other sources may have to be employed. These include the personal knowledge of local and provincial planning staffs, taxation statistics, and the co-operation of other bodies that possess some income information such as local credit bureaus.

Periodic random sampling could provide continuous monitoring of income for small statistical areas if the benefits of the analysis could be shown to offset the costs. If the income data were collected as part of normal survey work the added cost would be very small.

Centre Sales. With rare exceptions, annual sales for individual shopping centres are presently not available from any published source. The disclosure rules of Statistics Canada quite properly preclude their release. Users of the retail model are in no worse position than trade area analysts in this respect. A ratio of floorspace to sales was used in the case studies as the best substitute for accurate information on the annual sales of existing centres.

Elsewhere, planning staffs have been able to obtain independent confirmation of their estimates through local retailers, annual

reports of shopping centre operators and other financial institutions.

2. The analysis of the multiplicity of options tested in the two case-study municipalities amply demonstrates the ability of the model to handle a very large number of alternative patternings of retail distributions simultaneously in a short time at low cost.

   The amount of computer time required to produce a summary site table of the type used for illustrative purposes in the case-study chapters was only a matter of a few seconds. For example, the computer time required to run the Huff version was less than five seconds.

   All the tables produced in analyzing the options tested for Belleville or Oshawa using the Huff program amounted to only minutes. The full version of one test for one option for the Cullen program took only 109 seconds at an estimated cost for computer time of $1.42.

   The principal amount of time and effort required to establish an adequate high quality data base is measured in terms of weeks or even man-months. The same statement can be made about alternative patternings of residential areas, the road network, households, income and so forth.

3. The model demonstrated its usefulness in determining whether adequate provision has been made in a plan for future retail requirements. The Belleville options achieved equilibrium solutions in each of the study years. In Oshawa, the results of the options tested provided a clear picture to the planners of the direction to be followed in establishing an adequate supply of potential sites.

4. The impact of the introduction of added retail space at a given location on the remainder of the shopping centres is clearly shown in terms of customer flows, cash flows, sales-per-square-foot ratios and market shares.

5. Some measure of the degree of acceptability of one site over a number of alternative sites -- where more than one site is

under consideration and there appears to be justification for only a single centre -- can be obtained by examining the relative size of the average trip lengths. It can be assumed that the pattern of shopping centres with the lowest average trip length contributes most to customer satisfaction by providing convenient access to shopping facilities.

6. Where two proposed centres are located side-by-side, and there is ample justification for only one centre, criteria beyond the value judgements introduced by trade area analysis or the retail model must be introduced by local or regional government decision makers in any case.

7. The use of either version of the retail model obviously assists in establishing the initial desirable size and future phasing of expansion for a single centre or for a complex of centres. Problems of overstoring or understoring in one locality are quickly revealed.

8. The research program undertaken by the study team generally confirms the validity of suggestions for further research that have been put forward by others. As well, priorities for further specific areas of research have been considerably clarified.

AREAS FOR FURTHER STUDY

First priority in further research should be given to improvements of a practical, and more immediate, nature aimed at further modifying the two programs used in this study for planning purposes.

Second priority could then be given to research of a theoretical and behavioural nature to strengthen the underlying conceptual basis of the retail model and to incorporate more recent thinking of other researchers.

Operational Improvements

A number of substantial improvements and refinements have been

incorporated into the two programs presented in this report. In each case, the program output has been considerably expanded, and this is particularly true of the Cullen version.

Moreover, the outputs for each program are now more readily comparable, so that a much clearer and more detailed picture of the actual situation for any retail centre, existing or projected, is presented. Interpretation of the results for policy purposes is greatly facilitated.

There are a number of interesting possibilities for further modification. The following refinements, for example, could prove to be valuable. They could not be attempted in this study due to time constraints.

1. The incorporation of a neighbourhood printout in the Cullen version. This is one important advantage the revised version of the Huff and Blue program possesses. The customer and cash flow matrices given in the Cullen program are of great value. Nevertheless, the form of data output in the neighbourhood printout available in the Huff and Blue version is easier to read for some purposes.

2. The modification of the two programs to use identical data decks if further comparative testing of the usefulness of each is to be continued. At present, each program requires virtually the same data but arranged somewhat differently. Such an adaption would result in a considerable saving in time and keypunching costs, especially when a large number of zones and centres are involved. Some effort has already been devoted to this area. The remaining changes would likely require some program restructuring.

3. A review of calibration procedures and the possibility of introducing another calibration process into the Huff and the Cullen versions.

4. The incorporation of further refinements to include all levels in the hierarchy of centres and all expenditures suggested in recent advances made in the U.K. in multi-centred hierarchial versions.

Introducing operational modifications would help the user without altering the underlying concepts in any way.

On the other hand, the existing programs already allow a reasonably sophisticated analysis to be made.

The more reliable the data base used for analysis, the more reliable the two programs become as planning tools.

Thus the argument for making further program revisions is perhaps not as strong at this time as the case for incorporating new theoretical foundations into the retail gravity concept itself.

Theoretical Improvements

The retail trade area analysis approach has many underlying weaknesses as a working model. It is oriented almost entirely to the single centre study as the basic unit of analysis. It is of little value for describing either long-range or multi-centre retail strategies. Analytically, it is entirely dependent on the use of directly observable phenomena such as accessibility and traffic flow, population and its distribution, income, and existing and potential competition for describing the viability of any site or the probable spatial configurations of retail spending. No acknowledgement is made of less directly measurable, more behavioural elements which might affect a consumer's choice in a significant way.

The methodology is satisfactory from the viewpoint of a developer interested in a reliable estimate about the soundness of a particular retail development proposal. It serves as a guideline for deciding if a selected location is appropriate as an investment.

As a planning tool it is much less satisfactory. The step-by-step procedure requires the use of privileged information and a series of shrewd estimates at each stage. It is more characteristic of an art than a soundly based scientific approach.

Retail models are also static, and therefore do not formally predict future shopping patterns or capacities. They do provide, however, a quantitative analytic base from which predictions may be obtained by projecting certain variables.

It is possible to adjust individual parameters and variables within the models to discover the possible effects of time and to

test and generate alternative plans. This flexibility is a very attractive characteristic of the more recent models and makes them much more valuable as planning tools than trade area analysis.

The gravity model concept is not without weaknesses. It is heavily dependent on the same variables as trade area analysis. It has been suggested that success in formulating a model of individual or mass behaviour requires the inclusion of variables other than strictly economic factors. However, to do so would necessitate a much sounder understanding of individual choice behaviour than now exists.

The consumer does not seem to follow a wholly rational process when travel costs are traded off against the shopping centre's attractiveness. Habit and inertia have been suggested as being among the dominant influences.

Current models of analysing the shopping process have still only begun to approach the question of individual consumer behaviour. Macro-scale models for forecasting or planning purposes have great potential but to date are still only rough tools in the absence of knowledge of the true underlying variables.

Although encouraging results have been obtained, current versions may be little more than historical accidents in view of the absence of a theoretical connection between their empirically determined weights and exponents and the corresponding behavioural variables on which they rest.

Intervening Opportunities Model

Hayes discusses a further form of retail model proposed by Harris (Hayes 1968). This too is a probabilistic model. Its main postulates are that the number of shopping trips or sales from an origin in zone i to a destination at shopping centre j are proportional to the number of intervening opportunities.

Unlike the gravity model, interzonal distance does not appear explicitly. Instead, possible destinations are ranked in order of increasing impedance from the origin.

Although the model in practice resembles the retail model that has been tested here, some interesting improvements appear possible once further refinements and testing are done.

1. The model contains a specific provision to vary demand for different population classes.

2. The model contains a provision to vary consumer behaviour in accordance with the density of shopping opportunities.

3. Two kinds of market are recognized, home-based and work-based origins.

4. Wider description of consumer preference is possible.

5. Seven parameters are contained within the model although data for calibration purposes are not usually available and, therefore, when simplified to an operational form, the reduced version approximates a gravity type model.

Future Directions in Retail Modelling

Retail models, individually or cumulatively, provide much information to serve as guidelines towards decisions on retailing. There is still ample room, of course, both theoretically and practically, to improve on present methodologies.

The results of preliminary attempts at microanalytic modelling of consumer preferences and shopping patterns are only now beginning to appear. The work of MacKay is instructive in this regard (MacKay 1972, 1973).

An underlying weakness is the lack of behavioural information to support the variables and parameters used in gravity models. Two particularly unsatisfactory gaps in the information available for retail model building include:

1. a need for a better understanding as to how shopping will be carried out in the future, and

2. a need for further knowledge about the shopping behaviour of individuals and small groups instead of relying on the actions of large aggregates of people.

1. Changes in Retailing

A forecast of future shopping activity would have to try and answer two important questions. First, how will changes in the retail and service trades affect the "attractiveness" of different sizes and types of shopping centres? And second, how will changes

in the way that shopping is carried out be reflected in the consumer's trade-off between the cost of a journey and the purpose of the journey.

2. Consumer Behaviour

A better understanding of how people really perceive their choices in shopping has been advocated (Thompson 1966).

Thompson has concluded that a more interdisciplinary approach is needed in attempting to identify promising new avenues of theoretical and empirical investigation using modelling techniques.

It must be recognized that the geographic distribution of retail sales is the result of the summed reactions of many individuals, each free to make decisions given the perceived and real constraints with which the consumer is faced.

To build such notions into retail models would in effect call for a halt to further immediate research along the traditionally, empirically-oriented areas of investigation which the present retail models have followed.

A closer link would be needed between the empiricists and theorists to establish a truly inter-disciplinary viewpoint. Thompson suggests that this can be achieved if the following hypothesis is adopted:

> The fundamental factor affecting the geographic distribution of retail trade is the manner in which consumers organize their perceptions of the internal environment with which they are faced.

This would call for less emphasis on census and other published data sources as the principal basis for the operation of explanatory models, and more emphasis on consumer shopping strategies and survey research.

Studying how individuals interpret and make decisions about complex phenomena in experimental situations may well be of potential value in formulating more meaningful theories of shopping behaviour. This in turn, may serve as the basis of further attempts at model building and quantification in the area of retail area research. Thompson cites several examples to illustrate the importance of this approach including the work of Lynch on the

perception of the urban environment.

If the orientation of the individual is demonstrably subjective, this could be important to the problem of analysing shopping behaviour and the geographic distribution of retail patronage. Much could be gained from attempts to explain perception differences in terms of such measurable consumer attributes as length of residence, education, income, age, sex and social class.

Summary

It may be that advances in retail modelling can only be achieved by integrating knowledge from many fields and incorporating this into the model using the statistical mechanical methods of entropy.

This calls for the development of a proven theoretical basis to support the variables and parameters used in the application of quantitative analysis -- both on a micro and macro level -- when applying modelling techniques.

Such techniques would likely be used with even greater confidence if a multi-disciplinary approach could be devised for future studies of retail location and consumer behaviour.

Technical Appendix

Steps in Using the Programs

The purpose of the technical appendix is to outline the two computer programs used in the study as a means of familiarizing the reader with the operating procedures involved.

Obviously, the technical aspects of computer applications can appear somewhat confusing to the reader who is not acquainted with programming languages and computer techniques.

While the appendix has been included largely to assist those interested in actually conducting similar studies, the format adopted should not prevent those who must interpret the results from examining the procedures.

A full computer program consists of three parts.

First, there is the information that the computer must be given in advance so that it will have something with which to operate. This is called the input data.

Second, there is the set of instructions to the computer on what is to be done with the input data when it gets them. This is called the source program.

Finally, there is the printed result of the computer operations. This is called the output.

Input data consist of all the variables that are to be considered, the parameters of the model, the options that are available to the user and similar kinds of information.

In the case of the retail model, the input variables comprise such things as the number of centres under study, centre sizes, distances from residential areas to retail centres and retail

expenditure information. Output variables, on the other hand, are the results of the computations made by the computer.

Both input and output variables must be carefully specified to ensure that the results are reliable. If the information required for the program is not properly interpreted, the results could be useless. Similarly, results that are otherwise reliable could be seriously misconstrued if output variables are misread.

THE HUFF AND BLUE PROGRAM

The program developed by David L. Huff and Larry Blue has been revised in the course of the study and used to test the Huff version of the retail model.

The copy of the source program is accompanied by a simple set of step-by-step explanations serving as a basic guide to the prospective user.

The variables in the model are described and the names assigned to them for programming purposes are identified.

Here are detailed descriptions of the input data requirements and all the variables in the program's output.

The Source Program

A copy of the source program will be found in Annexure A. An effort has been made to reduce the program listing to a form which can be more readily interpreted by the reader.

Each step is accompanied by explanatory notes about the nature of the operation being performed. A simplified flow diagram has been added in the margin to illustrate the sequence of operations.

The source program is written in FORTRAN IV language and is suitable for use with any WATFOR compiler. Modifications may be necessary if it is run on another system.

To make the program somewhat easier to follow, it is useful to compare the basic Huff formulation with its corresponding translation into program language. For instance the notational version of the

model

$$S_{ij} = E_i \cdot \frac{\dfrac{A_j}{d_{ij}{}^{\lambda}}}{\sum\limits_{j=1}^{n} \dfrac{A_j}{d_{ij}{}^{\lambda}}}$$

appears in the program version as

$$ECB(J) = ECBT \cdot \frac{\dfrac{S(J)}{T(J)^{ALA3}}}{\sum\limits_{J=1}^{ENJ} \dfrac{S(J)}{T(J)^{ALA3}}}$$

The mathematical notations have been changed to machine readable variable names to match the conventions of the programming language being used. Explanations of each of the variables employed in translating from notational conventions to program conventions are found in Figure A-1. This will serve as an introduction to the way in which variables throughout the program are named and defined.

Description of the Input Data

The following punch cards are required as inputs into the program. The cards are described in the sequence in which they must appear. A number of options are available to the user and their use is described in some detail at the point at which the option can be invoked.

Title Card

Column	Notation	Definition
1-72	TITLE	As many as 72 alphanumeric characters may be employed to identify the study being undertaken. Any combination of characters, letters or numerals, up to a maximum of 72, may be used.

Control Card # 1

Column	Notation	Definition
1-10	ENI	A numerical value corresponding to the number of zones or statistical areas within the study region.
11-20	ENJ	A numerical value corresponding to the total number of retail locations within the area under study in any given run of the program. This value cannot exceed the value assigned to J in the DIMENSION statement.
21-30	EN1	A numerical value corresponding to the maximum number of iterations specified for the lambda search procedure. A suggested safe number to use is 50. On the other hand, if a value for lambda is specified and no parameter search procedure is desired EN1 must be set equal to 0. Consumer shopping survey data are required if the parameter search procedure is to be initiated.
31-40	EPSL	A value representing the minimum lambda increment employed in the Fibonacci search procedure. The value suggested by Huff and Blue is .00001. If no search is being conducted a 0 should be specified.
41-50	EPSE	The minimum error increment to be used in the Fibonacci search procedure. Huff and Blue suggest a value of .0000001. Again, a 0 should be specified if no search is to be executed. It should be noted that not all computer systems may be able to accept values for EPSL and EPSE as small as those suggested by Huff and Blue. Where this is the case and a search procedure is desired, a reduction of several decimal places should overcome this difficulty.

NOTATIONAL AND PROGRAM VARIABLES - HUFF

Mathematical Notation	Program Notation	Definition
P_{ij}	ET(J)	The probability of a consumer or household from a zone i shopping at a retail centre j.
C_i	CT	The number of consumers or households in a zone i.
B_i	BF	The average annual expenditure per consumer or household budgeted for a given class of goods in a zone i.
E_i	ECBT	The total retail expenditure available in a zone i.
S_{ij}	ECB(J)	The sales attracted to a centre j from a zone i.
A_j	S(J)	A measure of the attractiveness of a centre j, in this case floorspace.
d_{ij}	T(J)	A measure of the travel distance, time or cost from a zone i to a centre j.
j	J	A given retail centre j.
n	ENJ	The number of retail centres in a given study area.
λ	ALA3	A parameter estimated empirically to reflect the effect of travel distance, time or cost on various kinds of shopping trips.

Fig. A-1: Notational and Program Variables - Huff

51-60	RATE	A numerical value corresponding to some predetermined straight-line distance conversion factor, such as time, miles, cost, etc. For example, RATE could represent an average dollar cost per unit distance to be applied to all shopping trips. If no such conversion is desired a 1 must be punched. It is simplest to set RATE equal to 1 if actual distance data are to be used, though the value of this indicator is not critical in this case.
61-70	RFIND	An indicator that, when assigned a value of 0, will bring about a calculation and printout of R, the coefficient of correlation. A 0 must be entered if the lambda search is to be executed. Specification of the value 1 will cause this step to be omitted. It is necessary to enter a value of 1 only when no parameter search is desired.

Control Card # 2

Column	Notation	Definition
1-10	SITEN	An indicator that identifies any retail site j to be increased in size incrementally. This indicator should be punched as an integer value corresponding to the position of such a centre in the array of location cards. For example, if the third centre listed was to be incremented then 3 would be punched in this space. A 0 must be specified if no centres are to be incremented. If SITEN is not equal to 0, ASC, a control indicator on the following card, may be left blank. However, if SITEN is 0, ASC must be specified.
11-20	AVIND	An indicator that, when assigned the value of 1, brings about a recalculated neighbourhood and summary site printout using a determined

average lambda over all zones. In this case the optimum parameter values for each zone derived by the search procedure are summed and divided by the number of zones to arrive at an overall average. If AVIND is assigned a value of 1, PNT, an indicator on the same card, should also be 1. AVIND must equal 0 if this average lambda option is not desired.

21-30	PIT	An indicator that, when assigned the value 1, brings about a printout by zone of the Fibonacci search for the parameter lambda. No such printout is given if a 0 is punched. If AVIND is equal to 1, PIT should be assigned a value of 0.
31-40	PNT	An indicator that, when assigned the value 1, results in a printout of the sales and customer distribution to each centre by zone. Such a printout can be very useful but is likely to be very lengthy and thus most costly. A 0 must be specified if such output is to be suppressed and only summary site information is desired. However, if the parameter search option is incorporated PNT should equal 1 as the zonal printout cannot be properly suppressed in this case. Similarly, if AVIND is assigned a value of 1, PNT should also be 1.
41-50	CTRI	An indicator that determines how many sets of zone cards are to be read. There can be a maximum of 3 such sets. The first set must always be read and represents summary information for each zone. The second set represents actual consumer survey data and indicates the number of customers travelling from each zone to each centre. The third set represents actual distance data in terms of cost, travel time, miles, etc., again on a

zone i to centre j basis. If a 0 is specified, only the first set of cards will be read. If, however, actual consumer survey and/or distance data are also to be read, a 1 must be entered.

Control Card # 3

Column	Notation	Definition
1-10	ACDAT	An indicator that, when assigned a value of 1, specifies that actual distance data are to be used, i.e. 2 sets of zone cards are to be read. If ACDAT is equal to 0, then both actual consumer survey and distance data will be read, i.e., all 3 sets of zone cards are included. ACDAT must equal 0 if the lambda search process is desired. If neither actual distance nor consumer survey data are to be read, i.e., no search is to be conducted, the space for this indicator may be left blank. In this case CTRI should be specified as 0. If actual distance data are to be used but no lambda search is desired both CTRI and ACDAT must be assigned a value of 1.
11-20	EN2	A numerical value representing the number of paired values relating size of retail centre to profit percentage. This number cannot exceed the values associated with SL and FACT in the DIMENSION statement. If no profit or percentage profit calculations are to be made a value of 1 must be entered for this indicator.
21-30	OMCJ	An indicator that, when denoted by the value 1, causes the calculation of a component of the denominator of R, the coefficient of correlation, to be calculated. This value is to be used if the lambda search process is desired and RFIND equals 0. If, however, the opposite holds true and RFIND equals 1, OMCJ must be specified as 0.

31-40	OMPE	An indicator that, when assigned a value of 0, causes the calculation and printout of the profit at any centre j and the percentage profit factor for that centre to be omitted. If this step is to be included, however, this indicator must be assigned a value of 1. If OMPE is not equal to 0, then EN2 must be a value greater than 1.
41-50	DATA	An indicator that, when assigned a value of 1, ensures the termination of the program. If several data decks are to be run simultaneously DATA must equal 1 in the last deck and 0 in each preceding deck. If only a single deck is employed DATA must equal 1.
51-60	ASC	An indicator that, when assigned a value of 1, causes actual sales to be calculated within the program on the basis of given sales per square foot figures. If actual sales by centre are known, they may be read directly into the program. In this case, ASC must be set equal to 0. This indicator does not have to be specified if SITEN is assigned a value other than 0, since in this case actual sales are arrived at somewhat differently.

Parameter Specification Card

Column	Variable	Definition
1-10	ALASP	A predetermined value specified for the parameter lambda. If no search procedure is utilized, the first set of zone cards in the data deck will initially identify this predetermined value as ALA1. In subsequent runs, however, it is conceivable that the testing of alternative parameter values will be desired. To obviate the time consuming task of repunching the zone cards each time

a new parameter value is to be run the indicator ALASP may be used. The program, when run without a search procedure, will substitute for lambda the value specified by ALASP if ALA1 is originally specified as 1.0 on each zone card. If no change in the parameter value is desired ALASP should be set equal to ALA1. If the parameter search process is initiated, ALASP should coincide with the lower limit of lambda selected.

Profit Factor Card(s)

Column	Variable	Definition
1-10	SL(K)	A numerical value representing the size or scale of retail operation related to a given profit fraction.
11-20	FACT(K)	A numerical value representing the profit fraction associated with a given size or scale of retail operation.

One such card is required for each paired combination of SL(K) and FACT(K). The total number of profit factor cards must thus correspond to the value previously given to EN2 on control card # 3. If EN2 is set at 1, then only 1 card is required with both SL(K) and FACT(K) specified as 0.

Location Cards

Column	Variable	Definition
1-10	S(J)	A numerical value corresponding to the size in square feet of a given retail centre j.
11-20	XS(J)	The X co-ordinate of a given retail centre j calculated from a grid map of the study area.
21-30	YS(J)	The Y co-ordinate of a given retail centre j calculated from a grid map of the study area.

		These X and Y co-ordinates are used for the calculation of straight-line distances in the program. They are essential if no actual distance data is available. Where actual distance data is available and no straight-line output is desired, these co-ordinate values need not be specified.
31-40	DS(J)	A numerical value corresponding to the size increment that is to be applied to a given retail centre j if called for by the indicator SITEN on control card # 2. If no incrementing is to be done this space must be left blank. That is, if SITEN equals 0, no value is to be entered for DS(J).
41-50	SM(J)	A numerical value representing the number of times the size increment DS(J) is to be applied to a given retail centre j if called for by the indicator SITEN. Again, SITEN cannot equal 0 if a value is to be specified.

There will be one location card for each retail centre included in the study area. That is, the number of location cards must correspond to the value entered for ENJ on control card # 1. It is helpful to arrange these cards in descending order of size of retail footage. This allows the program to be run more readily for various ranges of centre sizes.

Combined Sales Per Square Foot Cards

Column	Variable	Definition
1-5	SLS(J)	An average retail sales per square foot value, i.e., FOOD and DSTM combined, associated with each centre in the study area. This value is to be specified only if site incrementing is desired. That is, SITEN cannot be 0. In this case, no data for AMKB(J), FOOD(J), DSTM(J), SLSF(J) or SLSD(J) can be included. A separate card is required for each centre.

Zone Cards: Set # 1

Column	Variable	Definition
1-10	CT	A numerical value corresponding to the total number of consumers or households in a given zone i.
11-20	ALA1	A numerical value representing the lower limit of the parameter lambda for a given zone i if a search procedure is being utilized. If no search is to be conducted, a predetermined value for lambda must be entered. It is simplest to assign ALA1 a value of 1.0 as lambda can then be easily respecified by the indicator ALASP on the Parameter Specification Card.
21-30	ALA2	A numerical value representing the upper limit of the parameter lambda for a given zone i if a search procedure is being utilized. If no search is to be conducted the space for this term must be left blank.
31-40	BF	A conversion factor on CT, the number of consumers or households in a zone i, representing retail expenditures for various products originating in that zone. In effect this represents the average annual income per consumer or household available for retail spending in a zone i. If no sales distribution (by centre) is desired or no income data are available, a 0 should be noted. This will result in a printout of the customer distribution only. In virtually all practical applications of the model, however, it is most important to specify income data in some form.
41-50	XN	The X co-ordinate of the centre of population gravity of a given zone i, usually the

		estimated centroid of the zone, calculated from a grid map of the study area.
51-60	YN	The Y co-ordinate of the centre of population gravity of a given zone i calculated from a grid map of the study area. These X and Y co-ordinates are also critical for the calculation of straight-line distances in the program. They are essential if no actual distance data are available but may be omitted if straight-line output is not required.

Zone Cards: Set # 2

Column	Variable	Definition
1-72	C(J)	A numerical value representing the actual number of shopping trips made from a given zone i to a given centre j. Provided that such data are available, each zone can have one corresponding consumer survey card(s). Each such card(s) represents the actual distribution of consumers from a given zone i to each centre j. A separate value for each centre j is required, with a maximum of 6 columns allowed per entry. Data for as many as 12 centres can be accommodated on a single card, with remaining centres being entered on additional cards as necessary. The indicators ACDAT and CTRI must equal 0 and 1 respectively if such data are to be read. If no figures for actual consumer distribution are available, no card(s) is required. In this case, the space for ACDAT must be left blank if actual distance data are also not to be used, or conversely, assigned a value of 1 if such data are available. Correspondingly, CTRI should be either 0 or 1.

Zone Cards: Set # 3

Column	Variable	Definition
1-72	T(J)	A numerical value representing the actual distance in travel time, cost, miles, etc., from a given zone i to a given centre j. Provided that actual data are to be used, each zone must have one corresponding distance card(s). Each such card(s) specifies the actual distances from a given zone i to each centre j. A separate distance value is entered for each centre, with a maximum of 6 columns allowed per entry. Up to 12 distance values can be noted on a single card, with additional values entered on extra cards as necessary. Again, the indicator ACDAT on control card # 3 must equal 0 if both actual consumer survey and actual distance data are to be used. If only actual distance figures are available, however, ACDAT must equal 1. If neither the second nor the third set of zone cards are to be used, the space for ACDAT should be left blank and CTRI should equal 0.

The total number of zone cards in each of the three possible sets must correspond to the value specified for EN1 on control card # 1. If actual consumer survey and distance data are to be utilized the following procedure must be adopted. Each zone card must be followed, first, by its corresponding consumer survey data (C(J)) card, and second by its corresponding distance data (T(J)) card. If only actual distances are to be employed, a distance data card must follow immediately after each zone card. The cards must be alternated for each zone in this manner.

Actual Retail Sales Card(s)

Column	Variable	Definition
1-70	AMKB(J)	A numerical value corresponding to the total annual dollar sales actually generated at a given retail centre j. Seven such values can

be accommodated per card with a maximum of 10 columns allowed per entry. Additional values are to be specified on extra cards if necessary. These values must be ordered so as to correspond to the array of location cards. The indicator ASC on control card # 3 must equal 0 if actual sales are given. Actual sales figures are usually not available, however, and must be estimated. If this is the case, this card(s) is to be omitted and the indicator ASC must equal 1. If SITEN is a value other than 0, this card(s) must also be omitted.

Floorspace Card(s): Set # 1

Column	Variable	Definition
1-70	FOOD(J)	A numerical value corresponding to the total retail floorspace in square feet at any given centre j devoted to the sale of food items.

Floorspace Card(s): Set # 2

Column	Variable	Definition
1-70	DSTM(J)	A numerical value corresponding to the total retail floorspace in square feet at any given centre j devoted to the sale of department store type merchandise. Values noted in each of the 2 sets of floorspace cards must correspond to the sequence of centres specified in the location cards. In each case seven values per card may be entered, with a maximum of 10 columns allowed per entry. Additional values must be specified on extra cards as necessary. No card(s) for either FOOD(J) or DSTM(J) can be included if SITEN has a value other than 0.

Sales Per Square Foot Cards

Column	Variable	Definition
1-10	SLSF(J)	A numerical value specifying the retail food sales per square foot assigned to each centre in the study area.
11-20	SLSD(J)	A numerical value specifying the retail DSTM sales per square foot assigned to each centre in the study area.

These variables provide one method of estimating actual annual retail sales. If no distinction in sales per square foot is to be drawn between any of the centres in the study area, identical values should be noted for each case, with a separate card included for each centre. However, it may be possible in some cases to determine individual sales per square foot values for each retail centre.

One example of a possible basis of differentiation would be the criterion of planned versus unplanned centres. In this case, one card per centre is entered as before, but values need not be the same. If either the indicator ASC is specified as 0, or SITEN is not equal to 0, no sales per square foot card(s) should be included with the input deck. If actual sales are to be estimated on the basis of these two variables, no input for AMKB(J) is necessary. It should also be noted that if AVIND is specified as 1, it is necessary to repeat the last 3 data cards in identical sequence, i.e., floorspace card(s): set # 1, floorspace card(s): set # 2, and sales per square foot card(s).

Description of the Output Variables

It will be readily apparent from the input data that a wide variety of options are available to the user. Although the selection of options will be determined in large measure by the nature of the information available for a given study area, the number of alternatives available still allows the user considerable flexibility. Consequently, the program can test the implications of a wide number of situations.

It follows, as well, that there will be a wide range of output variables associated with the program. The exact form of the printed results is dependent entirely upon the choice of control card indicators and the nature of the input data. A comprehensive listing has been prepared of all possible output variables produced by the program. The variables are defined in the sequence in which they appear in the body of the source program.

The nature of the application being made and the type of analysis to be attempted will determine the value to the user of each output variable. Obviously, not all output variables will appear in the results each time. The options specified by the control cards will determine those that are to appear. For the most part the output variables that do appear are given descriptive titles in place of program variable names. The equivalent forms are indicated in those instances where titles are employed in place of program variable names.

Output Variable	Definition
SL(K)	The size or scale of retail operation related to a given profit fraction.
FACT(K)	The profit fraction associated with a given size of retail operation. Both of these variables appear under the heading PROFIT FACTOR TABLE in the printout.
AV	A fractional value equivalent to 1 divided by the number of retail centres.
S2	A value corresponding to a component of the denominator of R, the coefficient of correlation.
SCJ	The total number of actual or observed consumers or households going to all centres from a given zone i, i.e., the sum of C(J).
A, B, ALAM(1), ALAM(2), ERR(1), ERR(2), ERRS	These variables are associated with the Fibonacci search procedure included in the Huff program. For specific use, see

A Programmed Solution for Estimating Retail Sales Potentials (Huff and Blue 1964).

Neighbourhood Printout (Outputs)

Output Variable	Definition
CT	The number of consumers or households in a given zone i.
XN	The X co-ordinate of the centroid of population gravity of any zone i.
YN	The Y co-ordinate of the centroid of population gravity of any zone i.
ALA1	The initial value of the lower limit assigned to the parameter lambda if the search option is utilized. If no search procedure is employed, ALA1 corresponds to a predetermined lambda value.
ALA2	The initial value of the upper limit assigned to the parameter lambda if the search option is utilized. If no search procedure is employed, the value 0 appears.
ALA3	The actual value of the parameter lambda for a given zone i. This value may be derived by means of the search procedure in which case it represents an optimum value. It may also represent an average lambda value calculated over all zones. Finally, if no search procedure is desired, it may be a value specified by the user, in which case it corresponds to ALA1.
R	The coefficient of correlation associated with a given value of lambda. This value of R may correspond to either of the 2 possible values associated with ALA3 if a search procedure is

utilized. The indicator RFIND must be specified as 0 or R will not be calculated, appearing as 0 in the printout. R cannot be calculated if the search process is omitted as the calculation of this coefficient is dependent upon the input of actual consumer survey data.

BF	The average annual consumer or household income available for retail spending in a zone i.
J	An integer number used to identify each retail centre j. This value appears under the heading SITE in the neighbourhood printout.
T(J)	The distance from a given zone i to a retail centre j. This value can represent either actual distance in terms of travel time, cost, etc., or calculated straight-line distance, depending on the option selected and the data available. This variable is identified as DIST in the neighbourhood printout.
EC(J)	The expected number of consumers or households originating in a zone i and shopping at a centre j. This variable is identified as CUST in the neighbourhood printout.
ECB(J)	The expected retail spending originating in a zone i and terminating at a centre j. In effect, this value represents the expected number of consumers from zone i shopping at centre j multiplied by the retail spending available at zone i. This variable appears under the heading EXPEND in the neighbourhood printout.
S(J)	The total retail floorspace in square feet at a given centre j. This variable is identified as SIZE in the neighbourhood printout.

XS(J)	The X co-ordinate of a given centre j. This value appears under the heading XS in the neighbourhood printout.
YS(J)	The Y co-ordinate of a given centre j. This value appears under the heading YS in the neighbourhood printout.
ET(J)	The probability of a consumer or household in a given zone i shopping at a given retail centre j. This variable is identified as HSHARE in the neighbourhood printout.
ECT	The sum of the EC(J) values for a given zone i. ECT thus represents the total number of consumers or households in a given zone and should correspond to the value for CT.
ECBT	The sum of the ECB(J) values for a given zone i. ECBT thus represents the total retail spending available in a given zone.
ETT	The sum of the ET(J) values for a given zone i. The sum of these individual probabilities must always be 1.0. This is the last variable to appear in the neighbourhood printout.
AVLAM	An average value of lambda calculated by summing the optimum parameter values for each zone and dividing by the number of zones.
PROF(J)	The dollar profit associated with a given retail centre j. This variable is identified as PROFIT in the printout.
PERC(J)	The percentage profit factor, determined from the profit factor table, associated with a given centre j. This variable is identified as PERCENT in the printout.

Summary Site Printout (Outputs)

Output Variable	Definition
J	An integer number used to identify each retail centre j. This value appears under the heading SITE in the summary site printout.
S(J)	The total retail floorspace in square feet at a given centre j. This variable appears under the heading SIZE in the summary site printout. The sum of these values is denoted in the program as T1.
FOOD(J)	The floorspace in square feet devoted to the sale of food items at a given centre j. This variable is identified as FOOD in the summary site printout. The sum of these values is denoted by T2.
DSTM(J)	The floorspace in square feet devoted to the sale of department store type merchandise at a given centre j. This variable is identified as DSTM in the summary site printout. The sum of these values is denoted by T3.
XS(J)	The X co-ordinate of a given centre j. This value appears under the heading XS in the summary site printout.
YS(J)	The Y co-ordinate of a given centre j. This value appears under the heading YS in the summary site printout.
TMKT(J)	The total number of consumers or households from all zones shopping at a given retail centre j. This variable appears as CUST in the summary site printout. The total number of consumers or households shopping at all centres is designated as T4.

TMKB(J) — The total retail sales generated by a given centre j as calculated by the model. This variable is identified as CAL SLS in the summary site printout. The sum of the calculated retail sales generated by all centres in the study area is designated as T5.

AMKB(J) — The actual sales generated by a given centre j. This variable is identified as ACT SLS in the summary site printout. The sum of the actual retail sales generated by all centres is denoted by T6.

RATIO(J) — The ratio of calculated sales to total floorspace at a given centre j. In effect, this variable represents the sales per square foot generated at a centre j as calculated by the model. This variable is identified as CS/FT in the summary site printout. The average calculated sales per square foot for all centres is denoted in the program by T7.

ACTRAT(J) — The ratio of actual sales to total floorspace at a given centre j. This variable represents the sales per square foot actually generated at a centre j and is identified as AS/FT in the summary site printout. The average actual sales per square foot for all centres is identified as T8.

FRTMK(J) — The percentage of total consumers or households in the study area patronizing a given centre j. This variable is identified as HH SH in the summary site printout. The sum of these percentages is denoted by T9.

SLSMK(J) — The percentage of total calculated sales generated by a given centre j. This variable is identified as CA$SH in the summary site printout. The sum of these percentages is

designated as T10.

ASLSMK(J) — The percentage of total actual sales generated by a given centre j. This variable is identified as AC$SH in the summary site output. The sum of these percentages is identified in the program as T11. This is the last variable to appear in the summary site output table.

THE CULLEN PROGRAM

The second program is based on the Cullen formulation of the retail gravity model incorporating the Wilsonian concepts of entropy. The version presented here is actually an extensive revision of a program developed by Ian Cullen at University College, London. The sequence of presentation is identical to that used for the presentation of the Huff version in the first part of this appendix.

The Source Program

A copy of the source program will be found in Annexure B. Explanatory notes and a flow diagram have been added in the same way as in the Huff version in Annexure A. This program is also written in FORTRAN IV.

The notational form of the Cullen version is

$$S_{ij} = \frac{E_i \cdot e^{\alpha A_j - \lambda d_{ij}}}{\sum_{j=1}^{n} e^{\alpha A_j - \lambda d_{ij}}}$$

In the program version it appears as

$$S(I,J) = \frac{YC(I)\ e^{\text{ALPHA (A(J)) - LAMBDA (D(I,J))}}}{\sum_{J=1}^{M} e^{\text{ALPHA (A(J)) - LAMBDA (D(I,J))}}}$$

The translation of the notational form of variables to the program form is explained in Fig. A-2.

NOTATIONAL AND PROGRAM VARIABLES - CULLEN

Mathematical Notation	Program Notation	Definition
E_i	YC(I)	The total retail expenditure available in a zone i.
S_{ij}	S(I,J)	The sales attracted to a centre j from a zone i.
A_j	A(J)	A measure of the attractiveness of a centre j, in this case total annual retail sales.
d_{ij}	D(I,J)	A measure of travel distance, time or cost from a zone i to a centre j.
i	I	A given zone i.
j	J	A given retail centre j.
n	M	The number of retail centres in a given study area.
α	ALPHA	A parameter estimated empirically to reflect the attractiveness of a centre j.
λ	LAMBDA	A parameter estimated empirically to reflect the effect of travel distance, time or cost on various kinds of shopping trips.

Fig. A-2: Notational and Program Variables - Cullen

Description of the Input Data

The instructions for the preparation of the input data in punch card form are listed below. The cards must be arranged in the same sequence in which they are described. The modified Cullen program provides the user with a variety of procedural options, each of which is fully outlined as it appears.

Study Area Card

Column	Variable	Definition
1-3	N	An integer value representing the number of residential zones in the study area.
4-6	M	An integer value representing the number of retail centres in the study area.

Control Card # 1

Column	Notation	Definition
1-2	NA	An indicator that, when assigned a value of 1, specifies that a calibration run is to be made. If a calibration run is not desired, column 2 must be left blank.
3-4	NB	An indicator that, when assigned a value of 1, specifies that a study year simulation run is to be made. If such a run is not desired, column 4 must be left blank.
5-6	NC	An indicator that, when assigned a value of 1, specifies that a projection run is to be made. If such a run is not desired, column 6 must be left blank.
7-8	NE	An indicator that specifies the number of periods into which a given time span is to be subdivided if a projection run is to be made. For example, if the base year was 1971 and

the design year 1976, a value of 5 would result in a printout for each year in this time period, i.e., 1972-1976. If NA or NB are specified as 1, this space should be left blank.

9-16	C	A numerical value identified as the constant of retail consumption. This is a fixed value used to convert consumer or household income to its retail spending equivalent. If left blank or specified as 0, this constant is calculated automatically from the input data. However, more reliable results are likely to be obtained if an actual value is provided. If consumer or household retail spending data are available the constant must be specified as 1.0. If either of the options associated with NG or NH are to be adopted C must also be specified as 1.0.
17-18	NF	An indicator that must be specified as 1 if travel cost data are input as straight-line centimetre distances. If this is not the case, this column must be left blank and some true measure of travel cost used for D(I,J).
19-20	NG	An indicator that, when assigned a value of 1, specifies that base year sales figures for M-1 of M centres are to be adjusted, each in proportion to the overall increment in total consumption implied by design year population and income data. This option should be specified only for a study year simulation run in which the last, i.e., Mth, sales figure input is a design year estimate for a proposed centre and all other sales figures relate to the base year. If this option is not desired NG should be left blank.

21-22	NH	An indicator that, when assigned a value of 0 or left blank, specifies that base year sales figures are to be adjusted as above for all, i.e., M centres. If NH is specified as 0, NG should equal 1. This option is to be used if a study year simulation run is being made on the basis of base year sales figures to test the effect of not introducing a proposed centre. If this option is not desired NH should be left blank. Summarizing, if neither option is desired both NG and NH must be left blank. If NG is assigned a value of 1 and NH is blank or 0, all centres will be adjusted. If both indicators are specified as 1, M-1 centres will be adjusted.

Control Card # 2

Column	Notation	Definition
1-3	ASC	An indicator that, when assigned a value of 1, causes actual sales to be calculated within the program on the basis of given sales per square foot figures. If actual sales by centre, i.e., A(J), are known they may be read directly into the program. In this case, ASC must be specified as 0.
4-6	DATA	An indicator that, when specified as 1, ensures the termination of the program. If a number of data decks are to be run simultaneously, DATA must equal 1 in the last deck and 0 in each preceding deck. If one deck only is used, DATA must be specified as 1.

Trip Length Card

Column	Notation	Definition
1-8	AST	A numerical value representative of the observed average shopping trip length in the

study area. If no such value is desired, a blank card must be inserted at this point.

Travel Speed Card

Column	Notation	Definition
1-8	V	A numerical value representing the average travel speed in miles per hour over the study area. A figure must be specified unless some actual measure of travel cost is utilized for D(I,J), in which case a blank card must be inserted. If V is left blank, the indicator NF on control card # 1 must also be left blank.

Distance Cards

Column	Variable	Definition
1-72	D(I,J)	A numerical value representing the cost of travelling from the centroid of a given residential zone i to a retail centre j. This value may simply be a straight-line centimetre distance measured from a standard grid map of the study area. In this case a distance conversion procedure may be applied by setting the indicator NF equal to 1. Alternatively, actual travel costs may be specified in terms of dollars, miles, time, etc., should such data be available. In this case, both NF and V should be left blank. As in the modified Huff and Blue program, a separate value is noted for each centre, with a maximum of 6 columns allowed per entry. This allows a maximum of 12 such values to be specified per card, with additional values noted on successive cards if needed. The cards must be arranged consecutively by zone with the total number of cards corresponding to the value of N specified in the study area card. The keypunching of distance data is one of

the more tedious and time-consuming tasks associated with the preparation of the input deck. It should be noted that the format used allows the same distance cards to be used in either of the 2 programs. Care must be taken, however, to (i) properly specify the associated control indicators, and (ii) to arrange the cards correctly.

Population Card(s)

Column	Variable	Definition
1-80	P(I)	A numerical value representing the number of consumers or households in a given residential zone i. Separate values must be noted for each zone, with a maximum of 10 columns allowed per entry. A maximum of 8 zonal population figures can thus be specified per card, with values being punched consecutively by zone on as many cards as required. If either a calibration run or a study year simulation run is being made these values correspond to study year zonal population. If, however, a projection run is being made they must correspond to design year population figures. In this latter case, base year data are included at the end of the data deck.

Floorspace Card(s): Set # 1

Column	Variable	Definition
1-70	FS(J)	A numerical value corresponding to the total retail floorspace in square feet at any given centre j.

Floorspace Card(s): Set # 2

Column	Variable	Definition
1-70	FOOD(J)	A numerical value corresponding to the total

retail floorspace in square feet at any given centre j devoted to the sale of food items.

Floorspace Card(s): Set # 3

Column	Variable	Definition
1-70	DSTM(J)	A numerical value corresponding to the total retail floorspace in square feet at any given centre j devoted to the sale of department store type merchandise.

Each set of floorspace cards is punched under an identical format. In each case up to seven values may be entered per card, with 10 columns available for each entry. Additional values are to be entered on extra cards as required. Values must be entered consecutively by centre. Since the format for the variables FOOD(J) and DSTM(J) coincides with that employed in the modified Huff and Blue program these data cards can be substituted in either of the two programs.

Sales Per Square Foot Cards

Column	Variable	Definition
1-10	SLSF(J)	A numerical value specifying the retail food sales per square foot assigned to each centre in the study area.
11-20	SLSD(J)	A numerical value specifying the DSTM sales per square foot assigned to each centre in the study area. If actual sales are to be estimated on the basis of these 2 variables, no input for the variable A(J) is necessary.

This input allows actual retail sales to be estimated for each centre on the basis of sales per square foot data. If this option is to be employed one card must be punched for each centre. If no distinction is to be made in sales per square foot, identical values should be entered on each card. Differential values may be used if individual sales per square foot estimates are available for each centre. These sales per square foot cards may also be substituted

into either of the two programs, as identical formats are required. If, however, the indicator ASC is specified as 0, no sales per square foot cards are required.

Income Card(s)

Column	Variable	Definition
1-80	Y(I)	A numerical value representing the average annual household or consumer income in dollars for a given residential zone i. This value is reduced to its retail spending equivalent by the consumption constant C entered on control card # 1. If, however, actual income budgeted for retail expenditure by zone is known, it may be specified accordingly. In this case, C must be specified as 1. If either a calibration run or a study year simulation run is being made, these data correspond to study year income figures. If, however, a projection run is to be made, these data must correspond to design year income. In this case, base year income data are included at the end of the data deck.

Actual Retail Sales Card(s)

Column	Variable	Definition
1-70	A(J)	A numerical value corresponding to the total annual dollar sales actually generated at a retail centre j. Seven such values can be entered per card with a maximum of 10 columns available for each entry. Data must be entered consecutively by centre and additional values must be specified on extra cards as necessary. If such data are available, ASC should be assigned a value of 0. If, however, actual sales for each centre are to be calculated within the program, ASC should

equal 1. In this case, no actual sales card(s) is required. This data card(s) may also be substituted into either of the two programs used in this study.

Calibration Parameter Card

This card is required only if the indicator NA on control card # 1 has a value of 1. If no value for NA is specified then this card is to be omitted.

Column	Variable	Definition
1-9	AL1	The initial value assigned to the attraction parameter, alpha, in the calibration run.
10-18	ALI	A numerical value specifying the size of the alpha increment selected for the calibration run.
19-20	IAL	An integer value specifying the number of increments to be used for the attraction parameter, alpha, in the calibration run.
21-29	ALAM1	The initial value assigned to the distance parameter, lambda, in the calibration run.
30-38	ALAMI	A numerical value specifying the size of the lambda increment selected for the calibration run.
39-40	ILAM	An integer value specifying the number of increments to be used for the distance parameter, lambda, in the calibration run.

Parameter Specification Card

This card is required only if either of the indicators NB or NC on control card # 1 is assigned a value of 1. This card is not required if a calibration run is to be made.

Column	Variable	Definition
1-9	ALPHA	The value assigned to the attraction parameter, alpha, if either a study year simulation run or a projection run is being made.
10-18	LAMBDA	The value assigned to the distance parameter, lambda, if either a study year simulation run or a projection run is being made. These parameter values are normally derived by means of a calibration run using base year data.

Base Year Population Card(s)

Column	Variable	Definition
1-80	PB(I)	A numerical value corresponding to the number of consumers or households in a given residential zone i in the base year. The format used is identical to that for the variable P(I). This card(s) is required only if a projection run is to be made.

Base Year Income Card(s)

Column	Variable	Definition
1-80	YB(I)	A numerical value corresponding to the average annual consumer or household income in dollars for a residential zone i in the base year. Again, this value may be reduced to its retail spending component by the consumption constant C. If actual retail spending data are available, C must be assigned a value of 1. The format used is identical to that for the variable Y(I). This card(s) is required only if a projection run is to be made.

Description of the Output Variables

The wide range of options available in the modified Cullen program is associated with an equally wide range of output variables.

The comments made about the output variables in the modified Huff and Blue version apply equally to the Cullen outputs (Pages 101-102). A complete listing of these variables follows.

Calibration Run Outputs

Output Variable	Definition
C	The constant used to convert total household or consumer income to its retail spending equivalent. This may be either a predetermined value specified on control card # 1, or it may be a value calculated within the program. This value is denoted as CONSUMPTION CONSTANT in the calibration run printout.
AST	The observed average shopping trip length in the study area. This is merely the value noted on the trip length card. This value is denoted as INPUT TRIP LENGTH in the calibration run printout.
K	An integer value used to number the output printed with each iteration specified in the calibration run.
DSQ	The sum of the squares of the differences between actual and calculated sales for each centre j. This value is calculated in subroutine DIFFSQ. It appears under the heading DIFFSQ in the calibration run printout. Theoretically, the parameter values associated with the minimum DSQ value best approximate reality.
R	The value of the coefficient of correlation calculated with each iteration specified in the calibration run. This value is calculated in subroutine CORR and is intended to reflect the degree of correlation between calculated and actual sales. It appears under the heading

CORR in the calibration run printout.

ASTL	An average shopping trip length calculated for the entire study area with each iteration specified in the calibration run. This variable appears under the heading TRIP LENGTH in the calibration run printout.
ALPHA	The value of the attraction parameter, alpha. A separate value is printed for each iteration specified in the calibration procedure. These values appear under the heading ALPHA in the calibration run printout.
LAMBDA	The value of the distance parameter, lambda. Again, a separate value is printed for each iteration specified in the calibration procedure. These values appear under the heading LAMBDA in the calibration run printout.
J	An integer number used to identify each retail centre j. This output is denoted by the heading SITE in the calibration run printout.
A(J)	The actual sales generated by a given retail centre j. This variable may be either estimated within the program or read directly from the data deck. It is identified by the heading INPUT SALES in the calibration run printout.
T(J)	The total retail sales generated by a given centre as calculated by the program using the parameter values associated with each iteration specified in the calibration run. This variable appears under the heading SYNTHESIZED SALES in the calibration run printout.

Study Year Simulation Run Outputs

Output Variable	Definition
DSQ	The sum of the squares of the differences between actual and calculated sales for each centre j. This value is calculated in subroutine DIFFSQ and provides an indication of the goodness of fit obtained by the model.
J	An integer number used to identify each retail centre j. This output is denoted under the heading SITE in the summary site printout.
FS(J)	The total retail floorspace in square feet at a given centre j. This variable is denoted as SIZE in the summary site printout. The sum of the total floorspace figures is designated in the program as T1.
FOOD(J)	The floorspace in square feet devoted to the sale of food items at any centre j. This variable appears under the heading FOOD in the summary site printout. The sum of the food floorspace figures is designated as T2.
DSTM(J)	The floorspace in square feet devoted to the sale of department store type merchandise at any centre j. This variable appears under the heading DSTM in the summary site printout. The sum of the DSTM floorspace figures is designated in the program as T3.
SUMT(J)	A value representing the average calculated trip length from all zones to a given centre j. This value reflects trip distances weighted by their associated customer flows. The average trip length over the entire study area is designated as T12 while the average trip length to each centre appears under the

heading AVTL in the summary site printout.

TMKT(J)	The total number of consumers or households from all zones shopping at a given centre j. This value is denoted by CUST in the summary site printout. The sum of these values is designated as T4 and should correspond to the study area population in terms of either consumers or households.
T(J)	The retail sales generated by a given centre j as calculated by the program. This value is referred to as synthesized sales and appears under the heading SYN SALES in the summary site printout. The sum of these values, that is, the total sales generated by all centres in the study area as calculated by the program, is noted as T5.
A(J)	The actual sales generated by a given retail centre j. This variable is denoted as ACT SALES in the summary site printout and may be either estimated within the program or read directly from the data deck. The total actual sales generated by all centres is noted in the program as T6.
RATIO(J)	The ratio of synthesized or calculated sales to total floorspace at a given centre j. This variable thus represents the sales per square foot generated at a centre j as calculated by the model. This variable is denoted as CS/FT in the summary site printout. The average calculated sales per square foot for all centres in the study area is designated as T7.
ACTRAT(J)	The ratio of actual sales to total floorspace at a given centre j. This variable represents the sales per square foot actually generated

at any given centre and is denoted by AS/FT in the summary site printout. The average actual sales per square foot for all centres within the study area is denoted by T8.

FRTMK(J)	The percentage of total consumers or households in the study area shopping at a centre j. This variable is denoted by HH SH in the summary site printout. The sum of these percentages is designated in the program as T9.
SLSMK(J)	The percentage of total calculated sales generated by any centre j. This variable is denoted by CA$SH in the summary site printout. The sum of these percentages is noted in the program as T10.
ASLSMK(J)	The percentage of total actual sales generated by a given centre j. This variable appears as AC$SH in the summary site printout. The sum of these percentages is denoted by T11.
I	An integer number used to identify each residential zone i in the listing of zonal retail spending.
YC(I)	The total amount budgeted for retail spending by all consumers or households in a residential zone i. This variable appears under the heading ZONAL RETAIL SPENDING.
C	The value of the consumption constant used to convert total household or consumer income to its retail spending equivalent.
ALPHA	The value of the attraction parameter, alpha, entered on the parameter specification card.
LAMBDA	The value of the distance parameter, lambda,

entered on the parameter specification card.

S(I,J) — The retail spending from a given residential zone i allocated to a centre j. These values are printed in a matrix format under the heading CASH FLOWS TO.

CD(I,J) — The number of consumers or households travelling from a given residential zone i to shop at a given centre j. These values also appear in a matrix format and are identified by the heading CUSTOMER FLOWS TO.

Projection Runs

The printed output from this version of the program is not entirely suitable for making projection runs. Projection runs are intended to allow the impact of new centres to be assessed at different points in time. That is, the existence of a new centre may be specified for any given year within a defined projection period. Consequently, it becomes possible to test numerous alternatives within a temporal framework. Certain additions to the body of the program are necessary, however, if such a run is to be made. One simple illustration is discussed below. The new cards that will be required are denoted by asterisks and appropriate explanations are provided throughout.

An Illustration

Assume that a projection is to be made with base year population and income data for 1971. Assume also that NE is specified as 5, that there are 6 shopping centres in the base year, and that a new centre is to be added in the third year of the projection period. In this case output would be provided for each of five years, 1972 through to 1976, with a new centre being introduced in 1974. The following additions would have to be made to the source program.

```
      .
      .
      .
140 CONTINUE
```

```
K = K+1.0
IF (K.GE.NE) GO TO 190
```

```
*IF (K.LT.3.0)M=6
```

The value assigned to K specifies the year in which the new centre will be added. In this case, if K is less than 3.0, the original number of centres will be retained. There will thus be 6 centres specified for 1972 and 1973.

```
*IF (K.GE.3.0)M=7
```

Once K is equal to 3.0 or greater, the new centre is introduced. The number of centres, M, has been increased by 1 for the period 1974-1976.

```
*IF (K.GE.3.0)FS(7)=200000
```

Since certain information about the new centre cannot be provided in the data deck, it must be presented at this point. First to be specified is the total floorspace in square feet of the new centre.

```
*IF (K.GE.3.0)FOOD(7)=30000
```

The floorspace devoted to the sale of food items must also be specified for the new centre.

```
*IF (K.GE.3.0)DSTM(7)=170000
```

Similarly, the floorspace devoted to the sale of department store type merchandise is also indicated for the new centre.

```
*IF (K.GE.3.0)A(7)=13500000
```

Finally, the actual sales likely to be generated by the new centre is specified. This will normally be calculated by applying estimated sales per square foot

to the floorspace figures anticipated.

```
    DO 142 I=1,N
          .
          .
          .
    MA=1
   *MB=6                        The dimensions of the cash flow matrix
                                are specified for the original number
                                of centres.
   *IF (K.GE.3.0)MB=7           The matrix is adjusted to include the
                                new centre at the time of its introduction.
172 CONTINUE
          .
          .
          .
    MA=1
   *MB=6                        The dimensions of the customer flow
                                matrix are similarly specified.
   *IF (K.GE.3.0)MB=7           The customer flow matrix is adjusted to
                                include the new centre.
176 CONTINUE
          .
          .
          .
```

The value entered for M on the study area card must correspond to the number of retail centres in the design or target year. Distance data must also be punched for all centres being considered in the project run. Similarly, one sales per square foot card

must be included for every centre. Finally, floorspace figures for any centres other than those found in the base year must be entered as 0. This applies to each set of floorspace cards, i.e., FS(J), FOOD(J) and DSTM(J). The output variables associated with the projection run are identical to those described for the study year simulation run.

The projection run affords the user with considerable flexibility in testing alternatives. Although this simple example has illustrated the addition of only one new centre, it is possible to introduce any number of proposed centres in any desired time sequence if the appropriate cards are added to the body of the program. These cards must be removed, however, if a calibration or a study year simulation run is to be made.

```
C     REVISED VERSION OF THE HUFF AND BLUE PROGRAM
C     HUFF RETAIL GRAVITY FORMULATION
C
C
      DIMENSION TITLE(18),C(99),T(99),S(99),XS(99),YS(99),          THE DIMENSION STATEMENT ALLOCATES SUFFICIENT MEMORY TO STORE
     1          TMKT(99),RATIO(99),EC(99),TMKB(99),ECB(99),         THE DATA CORRESPONDING TO EACH PROGRAM VARIABLE.  THIS
     2          ET(99),DS(99),SM(99),ALAM(2),ERR(2),FRTMK(99),      STATEMENT IS REPEATED IN THE SUBROUTINE AT THE END OF THE
     3          SL(99),FACT(99),PROF(99),PERC(99),AMKB(99),         PROGRAM.
     4          ACTRAT(99),FOOD(99),DSTM(99),SLSMK(99),
     5          ASLSMK(99),SLSF(99),SLSD(99),SLS(99)
C
      COMMON    TITLE,C,T,S,XS,YS,TMKT,RATIO,EC,TMKB,ECB,AMKB,      CERTAIN VARIABLES MUST BE ACCESSIBLE TO ALL PROGRAM SEGMENTS.
     1          ET,ALAM,ERR,M,NJ,CT,DS,SM,FRTMK,ALA2,SL,FACT,PERC   THIS STATEMENT ASSIGNS ALL SUCH VARIABLES TO A COMMON MEMORY
C                                                                   AREA.
      NIN=5                                                         MACHINE READER IS SPECIFIED.
      NOUT=6                                                        MACHINE PRINTER IS SPECIFIED.
      NAUX=1                                                        SCRATCH TAPE IS SPECIFIED.
    1 READ(NIN,900)TITLE                                            READ THE TITLE CARD.
FROM 280
      WRITE(NOUT,901)TITLE                                          PRINT THE TITLE CARD.
      REWIND NAUX                                                   REWIND TAPE.
      READ(NIN,902)ENI,ENJ,EN1,EPSL,EPSE,RATE,RFIND                 READ CONTROL CARD #1.
      READ(NIN,903)SITEN,AVIND,PIT,PNT,CTRI                         READ CONTROL CARD #2.
      READ(NIN,904)ACDAT,EN2,OMCJ,OMPE,DATA,ASC                     READ CONTROL CARD #3.
      READ(NIN,905)ALASP                                            READ THE PARAMETER SPECIFICATION CARD.
      N2=EN2
      READ(NIN,905)(SL(K),FACT(K),K=1,N2)                           READ THE PROFIT FACTOR CARD(S).
      WRITE(NOUT,906)                                               SPACING CONTROL.
      WRITE(NOUT,907)                                               PRINT THE HEADING PROFIT FACTOR TABLE.
```

```
      WRITE(NOUT,908)                                   PRINT THE HEADINGS SL(K) AND FACT(K).
      WRITE(NOUT,910)                                   SPACING CONTROL.
      WRITE(NOUT,909)(SL(K),FACT(K),K=1,N2)             PRINT THE PROFIT FACTOR TABLE.
      IF(SITEN.LT.1.0)ISM=1.0                           IF SITEN IS 0, NO INCREMENTING IS DONE.
      WRITE(NOUT,906)                                   SPACING CONTROL.
      IF(SITEN.GE.1.0)ISM=SITEN                         IF SITEN IS A POSITIVE VALUE THE CENTRE TO BE INCREMENTED IS
                                                        SPECIFIED.
      AVLAM=0.0                                         INITIALIZE AVLAM.
      NSKIP=1
      NI=ENI
      NJ=ENJ
      N1=EN1
      ALAT=0.0
      ENJA=ENJ
      AV=1.0/ENJA                                       A FRACTIONAL VALUE, ONE DIVIDED BY THE NUMBER OF CENTRES, IS
                                                        CALCULATED.
      WRITE(NOUT,906)                                   SPACING CONTROL.
      WRITE(NOUT,911)AV                                 PRINT THE VALUE FOR AV.
      FNM1=1.0
      FN=1.0
      IF(EN1.EQ.0.0)GO TO 5                             IF EN1 IS 0, THE FIBONACCI SEARCH IS OMITTED.
      DO 3 K=2,N1                                       THIS LOOP GENERATES THE LAST TWO OF N FIBONACCI NUMBERS IN
      FNT=FN                                            THE NUMBER OF ITERATIONS SPECIFIED BY EN1.
      FN=FNM1+FN
    3 FNM1=FNT
    5 CONTINUE
      READ(NIN,903)(S(J),XS(J),YS(J),DS(J),SM(J),J=1,NJ)   READ THE LOCATION CARD FOR EACH CENTRE J.
      IF(SITEN)8,8,6                                    IF SITE INCREMENTING IS SPECIFIED THE COMBINED SALES PER
    6 READ(NIN,912)(SLS(J),J=1,NJ)                      SQUARE FOOT CARDS ARE READ.
      DO 7 J=1,NJ
      AMKB(J)=S(J)*SLS(J)                               ACTUAL RETAIL SALES FOR EACH CENTRE ARE THEN ESTIMATED ON THE
                                                        BASIS OF THESE FIGURES.
```

`8 IF(SM(ISM).LT.1.0)ISM=1.0`	IF NO INCREMENTING IS SPECIFIED THE PREVIOUS STEP IS OMITTED.
`IF(SM(ISM).GE.1.0)ISM=SITEN`	
`SJS=S(ISM)`	
`DO 275 JS=1,ISM`	PREPARE FOR SITE INCREMENTING, IF SPECIFIED, FOR THE APPROPRIATE CENTRE.
`DO 9 J=1,NJ`	
`TMKT(J)=0.0`	
`TMKB(J)=0.0`	
`T(J)=0.0`	
`9 CONTINUE`	
`NAV1=1`	
`EJS=JS`	
`S(ISM)=SJS+(EJS-1.0)*DS(ISM)`	THE SIZE INCREMENT IS APPLIED.
`10 DO 200 I=1,NI`	BEGIN CALCULATIONS OVER ALL ZONES, ONE AT A TIME.
`IF(AVLAM)25,12,25`	IF AN AVERAGE VALUE FOR LAMBDA HAS BEEN DETERMINED, CONTROL PASSES TO STATEMENT 25.
`12 IF(JS-1)14,14,25`	CONTINUE UNLESS CONTROL IS PASSED TO STATEMENT 25.
`14 CONTINUE`	
`READ(NIN,904)CT,ALA1,ALA2,BF,XN,YN`	READ ZONE CARDS: SET #1.
`IF(ALA1.EQ.1.0)ALA1=ALASP`	IF ALAI IS ENTERED AS 1.0 ON EACH ZONE CARD, THE VALUE IS RESPECIFIED AS INDICATED ON THE PARAMETER SPECIFICATION CARD.
`WRITE(NAUX)CT,ALA1,ALA2,BF,XN,YN`	ZONE CARD DATA ARE ENTERED ON THE SCRATCH TAPE.
`IF(CTRI)15,20,15`	IF CTRI IS 0, OMIT THE FOLLOWING STEPS, OTHERWISE CONTINUE.
`15 IF(ACDAT)17,17,18`	IF ACDAT IS 0, CONSUMER SURVEY DATA ARE READ, IF IT IS 1, SUCH DATA ARE OMITTED.
`17 READ(NIN,913)(C(J),J=1,NJ)`	READ ZONE CARDS: SET #2 (CONSUMER SURVEY DATA).
`WRITE(NAUX)(C(J),J=1,NJ)`	ENTER THESE DATA ON THE SCRATCH TAPE.
`18 READ(NIN,913)(T(J),J=1,NJ)`	READ ZONE CARDS: SET #3 (ACTUAL DISTANCE DATA).
`WRITE(NAUX)(T(J),J=1,NJ)`	ENTER THESE DATA ON THE SCRATCH TAPE.
`20 CONTINUE`	
`GO TO 40`	
`25 CONTINUE`	

FROM 275

FROM 247

FROM 200

`READ(NAUX)CT,ALA1,ALA2,BF,XN,YN`	READ ZONE CARDS: SET #1, FROM THE TAPE.
`IF(CTRI)30,40,30`	IF CTRI IS 0, DO NOT READ THE FOLLOWING DATA.
`30 IF(ACDAT)35,35,37`	IF ACDAT IS 0, READ THE CONSUMER SURVEY AND ACTUAL DISTANCE DATA. IF IT IS 1, READ ACTUAL DISTANCE DATA ONLY.
`35 READ(NAUX)(C(J),J=1,NJ)`	READ CONSUMER SURVEY DATA FROM THE TAPE.
`37 READ(NAUX)(T(J),J=1,NJ)`	READ ACTUAL DISTANCE DATA FROM THE TAPE.
`40 CONTINUE`	
`DO 45 J=1,NJ`	
`IF(T(J))45,43,45`	IF ACTUAL DISTANCE DATA ARE NOT USED, STRAIGHT-LINE DISTANCES ARE CALCULATED ON THE BASIS OF CENTROID CO-ORDINATES. A DISTANCE CONVERSION FACTOR, RATE, MAY BE APPLIED.
`43 T(J)=RATE*SQRT((XN-XS(J))**2+(YN-YS(J))**2)`	
`45 CONTINUE`	
`IF(OMCJ)50,60,50`	IF OMCJ IS 0, CONTROL PASSES TO STATEMENT 60, OTHERWISE CONTINUE.
`50 SCJ=0.0`	
`S2=0.0`	
`DO 55 J=1,NJ`	THIS LOOP CALCULATES A COMPONENT OF THE DENOMINATOR OF R, THE COEFFICIENT OF CORRELATION.
`SCJ=SCJ+C(J)`	
`55 S2=S2+(C(J)/CT)**2`	
`IF(PIT.EQ.0.0)GO TO 60`	IF PIT EQUALS 0, CONTROL PASSES TO STATEMENT 60, OTHERWISE CONTINUE.
`WRITE(NCUT,901)TITLE`	PRINT THE TITLE CARD.
`WRITE(NOUT,906)`	SPACING CONTROL.
`WRITE(NOUT,914)I`	IDENTIFY EACH ZONE.
`WRITE(NOUT,915)`	PRINT THE HEADINGS S2, SCJ, AND CT.
`WRITE(NOUT,910)`	SPACING CONTROL.
`WRITE(NOUT,916)S2,SCJ,CT`	PRINT VALUES FOR THE ABOVE VARIABLES.
`60 CONTINUE`	
`IF(AVLAM)70,75,70`	IF AN AVERAGE LAMBDA VALUE HAS BEEN DETERMINED THE ACTUAL PARAMETER VALUE IS RESPECIFIED ACCORDINGLY.
`70 ALA3=AVLAM`	
`NAV1=2`	
`GO TO 110`	CONTROL PASSES TO STATEMENT 110. THE PARAMETER SEARCH IS OMITTED.
`75 IF(ALA2)79,78,79`	IF THE INITIAL VALUE OF THE UPPER LIMIT ASSIGNED TO LAMBDA IS NOT SPECIFIED, LAMBDA IS SET EQUAL TO THE VALUE INITIALLY ASSIGNED TO THE LOWER LIMIT OF LAMBDA.

TO 110

`79 CONTINUE`	THE FIBONACCI SEARCH IS INITIATED. END POINTS ARE INITIALIZED AND TRIAL VALUES OF LAMBDA ARE APPLIED.
`ERRS=100.0`	
`NT1=2`	
`A=ALA1`	
`B=ALA2`	
`DEL=(FNM1/FN)*(B-A)`	
`ALAM(1)=B-DEL`	
`ALAM(2)=A+DEL`	
`M=1`	
`CALL EVAL`	SUBROUTINE EVAL IS CALLED TO DETERMINE THE MINIMUM ERROR BETWEEN OBSERVED AND EXPECTED CONSUMER MOVEMENT ASSOCIATED WITH EACH LAMBDA VALUE.
`M=2`	
`80 CALL EVAL`	SUBROUTINE EVAL IS CALLED TILL THE ITERATIVE PROCESS IS COMPLETED.
`IF(PIT)81,88,81`	IF PIT IS 0, CONTROL PASSES TO STATEMENT 88, OTHERWISE CONTINUE.
`81 GO TO(85,86),NSKIP`	ITERATION PRINT CONTROL IS SPECIFIED.
`85 NSKIP=2`	
`WRITE(NOUT,906)`	SPACING CONTROL.
`WRITE(NOUT,917)`	PRINT HEADING FOR THE FIBONACCI SEARCH OUTPUT.
`WRITE(NOUT,906)`	SPACING CONTROL.
`86 CONTINUE`	
`WRITE(NOUT,918)`	PRINT THE FIBONACCI SEARCH OUTPUT.
`1A,B,ALAM(1),ALAM(2),ERR(1),ERR(2),ERRS`	
`88 CONTINUE`	
`IF(N1-NT1)121,121,90`	THE FOLLOWING SEQUENCE OF STATEMENTS CONSISTS OF CONTROLS TO STOP ERROR ITERATION AT THE APPROPRIATE POINTS.
`90 NT1=NT1+1`	
`IF(ABS(ERRS-ERR(M))-EPSE)122,122,92`	
`92 IF(ABS(ALAM(2)-ALAM(1))-EPSL)123,123,95`	
`95 DEL=ALAM(2)-ALAM(1)`	THE FOLLOWING STEPS TEST FOR THE DISCARDABLE LAMBDA REGION AS THE PROGRAM CONVERGES UPON AN OPTIMAL PARAMETER VALUE FOR EACH ZONE.

(TO 110) (FROM 98, 96)

`IF(ERR(2)-ERR(1))96,96,98`	THE REGION A TO ALAM(1) IS DISCARDED.
`96 A=ALAM(1)`	
`ERRS=ERR(1)`	
`M=2`	
`ALAM(1)=ALAM(2)`	
`ERR(1)=ERR(2)`	
`ALAM(2)=B-DEL`	
`GO TO 80`	CONTROL IS RETURNED TO STATEMENT 80.
`98 B=ALAM(2)`	THE REGION ALAM(2) TO B IS DISCARDED.
`ERRS=ERR(2)`	
`M=1`	
`ALAM(2)=ALAM(1)`	
`ERR(2)=ERR(1)`	
`ALAM(1)=A+DEL`	
`GO TO 80`	CONTROL IS RETURNED TO STATEMENT 80.
`110 CONTINUE`	ITERATION IS COMPLETED.
`IF(PNT)120,160,120`	IF PNT IS 0, CONTROL PASSES TO STATEMENT 160, OTHERWISE CONTINUE.
`120 CONTINUE`	
`WRITE(NOUT,901)TITLE`	PRINT THE TITLE CARD.
`WRITE(NOUT,919)`	PRINT FORMAT STATEMENT 919.
`GO TO 160`	CONTROL PASSES TO STATEMENT 160.
`121 WRITE(NOUT,901)TITLE`	PRINT THE TITLE CARD.
`WRITE(NOUT,920)N1`	PRINT FORMAT STATEMENT 920 AND THE VALUE OF N1.
`GO TO 170`	CONTROL PASSES TO STATEMENT 170.
`122 WRITE(NOUT,901)TITLE`	PRINT THE TITLE CARD.
`WRITE(NOUT,921)EPSE`	PRINT FORMAT STATEMENT 921 AND THE VALUE OF EPSE.
`GO TO 170`	CONTROL PASSES TO STATEMENT 170.
`123 WRITE(NOUT,901)TITLE`	PRINT THE TITLE CARD.
`WRITE(NOUT,922)EPSL`	PRINT FORMAT STATEMENT 922 AND THE VALUE OF EPSL.

```
160 CONTINUE
    R=0.0
    M=1
    ALAM(1)=ALA3
    CALL EVAL                          SUBROUTINE EVAL IS CALLED TO CALCULATE ET(J) THOUGH NO LAMBDA
                                       SEARCH IS CONDUCTED.
    IF(RFIND.NE.0.0)GO TO 180          IF RFIND IS A VALUE OTHER THAN 0, CONTROL PASSES TO STATEMENT
                                       180.
    GO TO 176                          CONTROL PASSES TO STATEMENT 176.
170 CONTINUE                           THE FOLLOWING STEPS ARE USED IN THE CALCULATION OF R, THE
                                       COEFFICIENT OF CORRELATION.
    IF(RFIND.NE.0.0)GO TO 180          IF RFIND IS A VALUE OTHER THAN 0, CONTROL PASSES TO STATEMENT
                                       180.
    IF(ERR(1)-ERR(2))172,174,174
172 M=1
    GO TO 175                          CONTROL PASSES TO STATEMENT 175.
174 M=2
175 CALL EVAL                          SUBROUTINE EVAL IS CALLED.
    ALA3=ALAM(M)
176 CONTINUE
    SPA=0.0
    SPJ2=0.0
    DO 179 J=1,NJ
    SPA=SPA+C(J)/CT*ET(J)
179 SPJ2=SPJ2+ET(J)*ET(J)
    SPJ1=SQRT(SPJ2)
    S1=SQRT(S2)
    U1=SQRT(ERR(M))
    RU=U1/(SPJ1+S1)
    RU1=1.0-RU                         AS A RESULT OF THE PRECEDING SEQUENCE OF OPERATIONS, R, THE
                                       COEFFICIENT OF CORRELATION, IS DETERMINED FOR EACH ZONE.
    R=(SPA-AV)/((SQRT(S2-AV))*(SQRT(SPJ2-AV)))
180 CONTINUE
```

`ECT=0.0`	
`ECBT=0.0`	
`ETT=0.0`	
`DO 182 J=1,NJ`	THE NUMBER OF CONSUMERS FROM ZONE I SHOPPING AT EACH CENTRE J IS CALCULATED AS THE PRODUCT OF THE PROBABILITY OF GOING TO CENTRE J TIMES THE POPULATION OF ZONE I.
`EC(J)=ET(J)*CT`	
`TMKT(J)=TMKT(J)+EC(J)`	
`ECB(J)=EC(J)*BF`	THE NUMBER OF CONSUMERS GOING TO CENTRE J IS MULTIPLIED BY THE AVERAGE HOUSEHOLD RETAIL SPENDING IN ZONE I.
`ECT=ECT+EC(J)`	THE TOTAL NUMBER OF CONSUMERS FROM ZONE I SHOPPING AT ALL CENTRES IS CALCULATED.
`ETT=ETT+ET(J)`	THE PROBABILITIES OF SHOPPING AT EACH CENTRE ARE SUMMED.
`ECBT=ECBT+ECB(J)`	THE RETAIL SPENDING FROM EACH ZONE I ALLOCATED TO ALL CENTRES IS SUMMED.
`182 TMKB(J)=TMKB(J)+ECB(J)`	
`IF(PNT)184,189,184`	IF PNT IS 0, CONTROL PASSES TO STATEMENT 189, OTHERWISE CONTINUE.
`184 WRITE(NOUT,906)`	SPACING CONTROL.
`WRITE(NOUT,914)I`	IDENTIFY EACH ZONE.
`WRITE(NOUT,906)`	SPACING CONTROL.
`WRITE(NOUT,923)`	PRINT FORMAT STATEMENT 923.
`WRITE(NOUT,924)CT,XN,YN,ALA1,ALA2,ALA3,R,BF`	PRINT THE VARIABLES INDICATED.
`WRITE(NCUT,906)`	SPACING CONTROL.
`WRITE(NOUT,925)`	PRINT THE HEADINGS FOR EACH VARIABLE IN THE ZONAL OR NEIGHBOURHOOD PRINTOUT.
`WRITE(NOUT,910)`	SPACING CONTROL.
`WRITE(NOUT,926)(J,T(J),EC(J),ECB(J),S(J),XS(J),YS(J),`	PRINT THE ZONAL OR NEIGHBOURHOOD OUTPUT TABLE.
`1ET(J),J=1,NJ)`	
`WRITE(NOUT,910)`	SPACING CONTROL.
`WRITE(NOUT,927)ECT,ECBT,ETT`	PRINT THE SUMMED VALUES OF TOTAL CONSUMERS, TOTAL RETAIL SPENDING AND SHOPPING PROBABILITIES FOR EACH ZONE I.
`189 CONTINUE`	
`NSKIP=1`	
`ALAT=ALAT+ALA3`	LAMBDA VALUES FOR ALL ZONES ARE SUMMED.
`190 DO 191 J=1,NJ`	
`191 T(J)=0.0`	

`AVLAM=ALAT/ENI`	THE AVERAGE LAMBDA VALUE IS CALCULATED BY DIVIDING THE PREVIOUS SUM BY THE NUMBER OF ZONES.
`ALAT=0.0`	
`WRITE(NOUT,928)`	SKIP TO A NEW PAGE.
`WRITE(NOUT,929)AVLAM`	PRINT AVERAGE LAMBDA AND ITS CORRESPONDING VALUE.
`WRITE(NOUT,906)`	SPACING CONTROL.
`IF(OMPE)212,226,212`	IF OMPE IS 0, PROFIT PERCENTAGE CALCULATIONS ARE OMITTED AND CONTROL PASSES TO STATEMENT 226. OTHERWISE THE FOLLOWING SEQUENCE OF STEPS LEADS TO THE CALCULATION OF THE PROFIT AND THE PERCENTAGE PROFIT FACTOR ASSOCIATED WITH EACH CENTRE J.
`212 CONTINUE`	
`DO 225 J=1,NJ`	
`DO 215 K=1,N2`	
`KA=K`	
`IF(S(J)-SL(K))217,217,215`	
`215 CONTINUE`	
`217 PERC(J)=(FACT(KA-1)+(S(J)-SL(KA-1))/`	
`1(SL(KA)-SL(KA-1))*(FACT(KA)-FACT(KA-1)))`	
`PROF(J)=TMKB(J)*PERC(J)`	
`PERC(J)=PERC(J)*100.0`	
`IF(EN2.EQ.1.0)GO TO 225`	IF EN2 EQUALS 1, CONTROL PASSES TO STATEMENT 225.
`WRITE(NOUT,906)`	SPACING CONTROL.
`WRITE(NOUT,930)`	PRINT THE HEADINGS SITE, PROFIT, AND PERCENT.
`WRITE(NOUT,910)`	SPACING CONTROL.
`WRITE(NOUT,931)J,PRCF(J),PERC(J)`	PRINT THE VALUES CORRESPONDING TO THE PRECEDING VARIABLES.
`225 CONTINUE`	
`226 CONTINUE`	
`IF(SITEN.EQ.0.0)GO TO 227`	IF SITEN IS EQUAL TO 0, CONTROL PASSES TO STATEMENT 227.
`GO TO 230`	OTHERWISE CONTROL PASSES TO STATEMENT 230.
`227 IF(ASC)228,228,229`	IF ASC IS SPECIFIED AS 0, ACTUAL SALES FOR EACH CENTRE ARE READ FROM THE ACTUAL RETAIL SALES CARD(S). OTHERWISE THIS STEP IS OMITTED.
`228 READ(NIN,902)(AMKB(J),J=1,NJ)`	
`229 CONTINUE`	

`READ(NIN,902)(FOOD(J),J=1,NJ)`	READ THE FOOD FLOORSPACE CARD(S): SET #1.
`READ(NIN,902)(DSTM(J),J=1,NJ)`	READ THE DSTM FLOORSPACE CARD(S): SET #2.
`READ(NIN,905)(SLSF(J),SLSD(J),J=1,NJ)`	READ THE SALES PER SQUARE FOOT CARDS.
`230 CONTINUE`	
`T1=0.0`	ALL VARIABLES IN THE SUMMARY SITE PRINTOUT ARE INITIALIZED.
`T2=0.0`	
`T3=0.0`	
`T4=0.0`	
`T5=0.0`	
`T6=0.0`	
`T7=0.0`	
`T8=0.0`	
`T9=0.0`	
`T10=0.0`	
`T11=0.0`	
`DO 238 J=1,NJ`	
`T1=T1+S(J)`	THE TOTAL FLOORSPACES FOR ALL CENTRES ARE SUMMED.
`IF(SITEN.EQ.0.C)GO TC 231`	IF SITEN IS 0, CONTROL PASSES TO STATEMENT 231. IF INCREMENTING IS SPECIFIED FOOD AND DSTM FLOORSPACE TOTALS ARE NOT CALCULATED AND CONTROL PASSES TO STATEMENT 232.
`GO TO 232`	
`231 T2=T2+FOCD(J)`	OTHERWISE, FOOD FLOORSPACES FOR ALL CENTRES ARE SUMMED.
`T3=T3+DSTM(J)`	SIMILARLY, DSTM FLOORSPACE FOR ALL CENTRES ARE SUMMED.
`232 CCNTINUE`	
`T4=T4+TMKT(J)`	THE TOTAL NUMBER OF CONSUMERS FROM ALL ZONES SHOPPING AT EACH CENTRE IS CALCULATED.
`T5=T5+TMKB(J)`	THE CALCULATED RETAIL SALES GENERATED BY ALL CENTRES ARE SUMMED.
`IF(SITEN.EQ.0.0)GO TC 233`	IF SITEN IS 0, CONTROL PASSES TO STATEMENT 233. IF INCREMENTING IS SPECIFIED, CONTROL PASSES TO STATEMENT 235.
`GO TO 235`	
`233 IF(ASC)235,235,234`	IF THE INDICATOR ASC HAS A VALUE OF 1, ACTUAL SALES ARE CALCULATED BY MULTIPLYING EACH FLOORSPACE COMPONENT BY ITS CORRESPONDING SALES PER SQUARE FOOT.
`234 AMKB(J)=(FOOD(J)*SLSF(J))+(DSTM(J)*SLSD(J))`	
`235 T6=T6+AMKB(J)`	THE ACTUAL ESTIMATED SALES FOR ALL CENTRES ARE SUMMED.

`T7=T5/T1`	THE AVERAGE CALCULATED SALES PER SQUARE FOOT FOR ALL CENTRES IN THE STUDY AREA IS DETERMINED.
`ACTRAT(J)=AMKB(J)/S(J)`	THE ESTIMATED ACTUAL SALES PER SQUARE FOOT FOR ALL CENTRES ARE DETERMINED.
`T8=T6/T1`	THE AVERAGE ESTIMATED ACTUAL SALES PER SQUARE FOOT FOR ALL CENTRES IS CALCULATED.
`238 CONTINUE`	
`DO 239 J=1,NJ`	
`FRTMK(J)=TMKT(J)/T4*100.0`	THE PERCENTAGE OF CONSUMERS ATTRACTED TO EACH CENTRE IS CALCULATED.
`T9=T9+FRTMK(J)`	THESE PERCENTAGES ARE SUMMED.
`SLSMK(J)=TMKB(J)/T5*100.0`	THE CALCULATED SALES AT EACH CENTRE IS COMPUTED AS A PERCENTAGE OF TOTAL CALCULATED SALES.
`T10=T10+SLSMK(J)`	THESE PERCENTAGES ARE SUMMED.
`ASLSMK(J)=AMKB(J)/T6*100.0`	THE ESTIMATED ACTUAL SALES AT EACH CENTRE IS CALCULATED AS A PERCENTAGE OF TOTAL ESTIMATED SALES.
`239 T11=T11+ASLSMK(J)`	THESE PERCENTAGE VALUES ARE ALSO SUMMED.
`WRITE(NOUT,901)TITLE`	PRINT THE TITLE CARD.
`WRITE(NOUT,906)`	SPACE CONTROL.
`WRITE(NOUT,932)`	PRINT THE HEADING SUMMARY SITE INFORMATION.
`WRITE(NOUT,906)`	SPACING CONTROL.
`IF(SITEN.EQ.0.0)GO TC 240`	IF NO INCREMENTING IS SPECIFIED, CONTROL PASSES TO STATEMENT 240.
`GO TO 241`	OTHERWISE, CONTROL PASSES TO STATEMENT 241.
`240 WRITE(NOUT,933)`	PRINT THE HEADING FOR THE SUMMARY SITE PRINTOUT.
`WRITE(NOUT,910)`	SPACING CONTROL.
`WRITE(NOUT,934)`	PRINT THE SUMMARY SITE OUTPUT TABLE.
`1(J,S(J),FOOD(J),DSTM(J),XS(J),YS(J),TMKT(J),TMKB(J),AMKB(J),`	
`2RATIO(J),ACTRAT(J),FRTMK(J),SLSMK(J),ASLSMK(J),J=1,NJ)`	
`WRITE(NOUT,910)`	SPACING CONTROL.
`WRITE(NOUT,935)T1,T2,T3,T4,T5,T6,T7,T8,T9,T10,T11`	PRINT THE TOTALS OF THE APPROPRIATE VARIABLES IN THE SUMMARY SITE PRINTOUT.
`WRITE(NOUT,928)`	SKIP TO NEXT PAGE.
`GO TO 242`	CONTROL PASSES TO STATEMENT 242.
`241 WRITE(NOUT,936)`	IF SITE INCREMENTING IS APPLIED, A SLIGHTLY DIFFERENT SUMMARY SITE HEADING IS PRINTED.
`WRITE(NOUT,910)`	SPACING CONTROL.

	`WRITE(NOUT,937)`	THE SUMMARY SITE OUTPUT TABLE ASSOCIATED WITH THE SITE INCREMENTING OPTION IS PRINTED.
	`1(J,S(J),XS(J),YS(J),TMKT(J),TMKB(J),AMKB(J),RATIO(J),`	
	`2ACTRAT(J),FRTMK(J),SLSMK(J),ASLSMK(J),J=1,NJ)`	
	`WRITE(NOUT,910)`	SPACING CONTROL.
	`WRITE(NOUT,938)T1,T4,T5,T6,T7,T8,T9,T10,T11`	SUMMARY SITE TOTALS ARE PRINTED FOR THE ABOVE CASE.
	`242 IF(JS-1)244,243,244`	CONTROL PASSES TO STATEMENT 243 OR 244.
	`243 CONTINUE`	
	`ENDFILE NAUX`	ERASE TAPE.
	`244 CONTINUE`	
TO 10	`REWIND NAUX`	REWIND TAPE.
	`IF(AVIND)245,250,245`	IF AVIND IS 0, CONTROL PASSES TO STATEMENT 250, OTHERWISE CONTINUE.
	`245 GO TO(246,250),NAV1`	
	`246 DO 247 J=1,NJ`	
	`TMKT(J)=0.0`	VARIABLES ARE INITIALIZED FOR THE AVERAGE LAMBDA VALUE RUN.
	`TMKB(J)=0.0`	
	`247 T(J)=0.0`	
	`GO TO 10`	CONTROL IS RETURNED TO STATEMENT 10 AND THE ENTIRE PROCESS IS REPEATED WITH AN AVERAGE LAMBDA VALUE.
TO 8	`250 AVLAM=0.0`	
TO 1	`275 CONTINUE`	
	`IF(DATA)280,280,300`	IF THIS INDICATOR IS 1, CONTROL PASSES TO STATEMENT 300. IF DATA IS 0, CONTROL IS RETURNED TO STATEMENT 1 AND THE ENTIRE PROCESS IS REPEATED USING A NEW DATA DECK.
	`280 CONTINUE`	
	`GO TO 1`	
TO 300	`900 FORMAT (18A4)`	THE FOLLOWING CARDS, NUMBERED 900 THROUGH TO 938 SPECIFY THE FORMATS ASSOCIATED WITH ALL WRITE STATEMENTS FOUND IN THE BODY OF THE PROGRAM.
	`901 FORMAT ('1',18A4)`	
	`902 FORMAT (7F10.0)`	
	`903 FORMAT (5F10.0)`	
	`904 FORMAT (6F10.0)`	
	`905 FORMAT (2F10.0)`	
	`906 FORMAT ('0')`	

```
908 FORMAT ('0',4X,'SL(K)',7X,'FACT(K)')
909 FORMAT (' ',F10.0,F12.4)
910 FORMAT (' ')
911 FORMAT ('0',4X,'AV=',F10.4)
912 FORMAT (F5.0)
913 FORMAT (12F6.0)
914 FORMAT ('0','NBHD',I4)
915 FORMAT ('0',10X,'S2',7X,'SCJ',7X,'CT')
916 FORMAT (' ',4X,3F10.4)
917 FORMAT ('0',7X,'A',11X,'B',8X,'ALAM(1)',5X,'ALAM(2)',
   16X,'ERR(1)',6X,'ERR(2)',7X,'ERRS')
918 FORMAT (' ',7F12.7)
919 FORMAT (' ','LAMBDA GIVEN, NO SEARCH FOR THIS NBHD')
920 FORMAT (' ','LAMBDA SEARCH ENDED ON NUM ITERATIONS FOR THIS NBHD G
   1T',I6)
921 FORMAT (' ','LAMBDA SEARCH ENDED ON ERROR DELTA FOR THIS NBHD LT',
   1F12.8)
922 FORMAT (' ','LAMBDA SEARCH ENDED ON DELTA LAMBDA FOR THIS NBHD LT'
   1,F12.8)
923 FORMAT (' ',6X,'CT',8X,'XN',8X,'YN',5X,'ALA1',6X,'ALA2',
   16X,'ALA3',9X,'R',8X,'BF')
924 FORMAT (3F10.2,4F10.4,F10.2)
925 FORMAT (' ',3X,'SITE',8X,'DIST',6X,'CUST',5X,'EXPEND',
   15X,'SIZE',9X,'XS',8X,'YS',6X,'HSHARE')
926 FORMAT (' ',I6,3X,F10.2,F10.0,F12.0,F10.0,3F10.2)
927 FORMAT (' ',3X,'TOTAL',11X,F10.0,F12.0,30X,F10.2)
928 FORMAT ('1')
929 FORMAT ('0','AVERAGE LAMBDA=',F8.4)
```

```
930 FORMAT (' ','SITE',5X,'PRCFIT',4X,'PERCENT')
931 FORMAT (' ',1X,I2,1X,F12.0,3X,F7.3)
932 FORMAT (' ',45X,'SUMMARY SITE INFCRMATICN')
933 FORMAT (' ','SITE',5X,'SIZE',7X,'FOOD',5X,'DSTM',9X,'XS',
   18X,'YS',6X,'CLST',5X,'CAL SLS',5X,'ACT SLS',4X,'CS/FT',
   23X,'AS/FT',3X,'HH SH',3X,'CA$SH',3X,'AC$SH')
934 FORMAT (' ',1X,I2,2X,3F10.0,2F10.2,F10.0,2F12.0,5F8.2)
935 FORMAT (' ','TOTAL',3F10.0,20X,F10.0,2F12.0,5F8.2)
936 FORMAT (' ','SITE',5X,'SIZE',9X,'XS',8X,'YS',6X,'CLST',
   15X,'CAL SLS',5X,'ACT SLS',4X,'CS/FT',3X,'AS/FT',3X,
   2'HH SH',3X,'CA$SH',3X,'AC$SH')
937 FORMAT (' ',1X,I2,2X,F10.0,2F10.2,F10.0,2F12.0,5F8.2)
938 FORMAT (' ','TOTAL',F10.0,20X,F10.0,2F12.0,5F8.2)
300 CONTINUE
    STOP                                              THE PROGRAM IS TERMINATED.
    END
    SUBROUTINE EVAL
C
    DIMENSION TITLE(18),C(99),T(99),S(99),XS(99),YS(99),
   1          TMKT(99),RATIO(99),EC(99),TMKB(99),ECB(99),
   2          ET(99),DS(99),SM(99),ALAM(2),ERR(2),FRTMK(99),
   3          SL(99),FACT(99),PROF(99),PERC(99),AMKB(99),
   4          ACTRAT(99),FOOD(99),DSTM(99),SLSMK(99),
   5          ASLSMK(99),SLSF(99),SLSD(99),SLS(99)
C
    COMMON    TITLE,C,T,S,XS,YS,TMKT,RATIC,EC,TMKB,ECB,AMKB,
   1          ET,ALAM,ERR,M,NJ,CT,DS,SM,FRTMK,ALA2,SL,FACT,PERC
C
    M=M
```

FROM 275

```
      DO 350 J=1,NJ
      ET(J)=0.0
      IF(T(J))350,350,340
  340 ET(J)=T(J)**(-ALAM(M))*S(J)
      SSOTJ=SSOTJ+ET(J)
  350 CONTINUE
      ERR(M)=0.0
      DO 375 J=1,NJ
      ET(J)=ET(J)/SSOTJ
      IF(ALA2)370,375,370
  370 ERR(M)=ERR(M)+(C(J)/CT-ET(J))**2
  375 CONTINUE
      RETURN
      END
```

DIFFERENCES BETWEEN OBSERVED AND EXPECTED CONSUMER FLOWS FROM EACH ZONE TO EACH CENTRE. OBSERVED VALUES ARE INPUT AS C(J) IN THE FORM OF CONSUMER SURVEY DATA (ZONE CARDS: SET #2). EXPECTED VALUES ARE DETERMINED BY CALCULATING THE PROBABILITY OF SHOPPING AT EACH CENTRE, ET(J), BASED ON THE PRODUCT OF FLOORSPACE TIMES DISTANCE RAISED TO THE POWER LAMBDA. THE DISCREPANCY OR ERROR BETWEEN OBSERVED AND EXPECTED VALUES IS CALCULATED FOR THE SPECIFIED NUMBER OF ITERATIONS. THE VALUE OF LAMBDA YIELDING THE MINIMUM ERROR IS THE BEST FIT PARAMETER VALUE FOR A GIVEN ZONE I. THIS VALUE IS THEN APPLIED IN THE BODY OF THE PROGRAM.

Annexure B

`C`	
`C`	
`C     REVISED VERSION OF THE CULLEN PROGRAM`	
`C     WILSON ENTROPY FORMULATION`	
`C`	
`C`	
`C`	
`C`	
`      COMMON/AA/A,T,M,N/BB/D,S,ALPHA,LAMBDA,YC/CC/R/DD/DSQ`	CERTAIN VARIABLES MUST BE ACCESSIBLE TO ALL PROGRAM SEGMENTS. THIS STATEMENT ASSIGNS THESE VARIABLES TO A COMMOM MEMORY AREA.
`C`	
`      DIMENSION D(70,40),P(70),Y(70),YC(70),S(70,40),A(40),` `     1          T(40),PB(70),YB(70),YBC(70),YDC(70),FS(40),` `     2          FOOD(40),DSTM(40),SUMT(40),RATIO(40),YYB(70),` `     3          ACTRAT(40),FRTMK(40),SLSMK(40),ASLSMK(40),` `     4          TMKT(40),AVT(70,40),CD(70,40),SUMTL(40),` `     5          SLSF(40),SLSD(40)`	THE DIMENSION STATEMENT ALLOCATES SUFFICIENT MEMORY TO STORE THE DATA CORRESPONDING TO EACH VARIABLE IN THE PROGRAM. SIMILAR COMMON AND DIMENSION STATEMENTS APPEAR IN THE THREE PROGRAM SUBROUTINES.
`C`	
`C`	
`      REAL*4LAMBDA`	LAMBDA IS DECLARED AS A REAL VARIABLE.
`    1 READ 1000,N,M`	READ STUDY AREA CARD.
`      READ 1001,NA,NB,NC,NE,C,NF,NG,NH`	READ CONTROL CARD #1.
`      READ 1000,ASC,DATA`	READ CONTROL CARD #2.
`      READ 1002,AST`	READ TRIP LENGTH CARD.
`      READ 1002,V`	READ TRAVEL SPEED CARD.
`      DO 2 I=1,N` `    2 READ 1003,(D(I,J),J=1,M)`	THIS LOOP READS THE DISTANCES FROM EACH ZONE I TO EACH CENTRE J.
`      READ 1004,(P(I),I=1,N)`	READ THE POPULATION OF EACH ZONE I.
`      READ 1005,(FS(J),J=1,M)`	READ THE TOTAL FLOORSPACE OF EACH CENTRE J.
`      READ 1005,(FOOD(J),J=1,M)`	READ THE FOOD FLOORSPACE OF EACH CENTRE J.

FROM 192

```
      READ 1006,(SLSF(J),SLSD(J),J=1,M)            READ THE FOOD AND DSTM SALES PER SQUARE FOOT FOR EACH
                                                   CENTRE J.
      IF(NF)5,5,3                                  IF THE INDICATOR NF IS 1, CENTIMETRE STRAIGHT-LINE DISTANCES
                                                   ARE CONVERTED TO AN APPROXIMATE TRAVEL-TIME EQUIVALENT.
    3 DO 4 I=1,N                                   OTHERWISE THIS LOOP IS OMITTED.  THIS STEP IS NOT USED WHERE
                                                   ACTUAL DISTANCE DATA ARE AVAILABLE.
      DO 4 J=1,M
    4 D(I,J)=(2.0*(SQRT(D(I,J)**2/2.0)))*(23.622/V)
    5 CONTINUE
      READ 1007,(Y(I),I=1,N)                       READ THE AVERAGE HOUSEHOLD INCOME FOR EACH ZONE I.
      IF(ASC)10,10,7                               IF THE INDICATOR ASC IS SPECIFIED AS 1, THE ACCOMPANYING
                                                   LOOP ESTIMATES ACTUAL SALES FOR EACH CENTRE J ON THE BASIS
    7 DO 9 J=1,M                                   OF SALES PER SQUARE FOOT FOR FOOD AND DSTM MERCHANDISE.
    9 A(J)=(FOOD(J)*SLSF(J))+(DSTM(J)*SLSD(J))
      GO TO 15
   10 READ 1005,(A(J),J=1,M)                       IF ASC IS 0, THIS LOOP IS BYPASSED AND ACTUAL SALES FOR EACH
                                                   CENTRE J ARE READ.
   15 IF(NG)30,30,18                               IF THE INDICATOR NG IS 1, ACTUAL SALES FOR EITHER M OR M-1
                                                   CENTRES MAY BE ADJUSTED IN PROPORTION TO THE OVERALL INCREMENT
   18 SUM6=0.0                                     IN CONSUMPTION IMPLIED BY DESIGN YEAR DATA.
      SUM7=0.0
      MM=M-1                                       THE NUMBER OF CENTRES TO BE ADJUSTED IS SPECIFIED AS M-1.
      IF(NH.EQ.0)MM=M                              IF THE INDICATOR NH IS 0, SALES ARE ADJUSTED FOR ALL, I.E.,
                                                   M CENTRES.
      DO 20 J=1,MM
   20 SUM6=SUM6+A(J)                               RETAIL SALES FOR ALL CENTRES ARE SUMMED.
      DO 25 I=1,N
   25 SUM7=SUM7+Y(I)*P(I)                          SIMILARLY, THE PRODUCTS OF ZONAL INCOME AND POPULATION, I.E.,
                                                   ZONAL RETAIL SPENDING, ARE ALSO SUMMED.  THIS LATTER SUM IS
      ZG=C*SUM7/SUM6                               DIVIDED BY THE SUM OF RETAIL SALES FOR ALL CENTRES AND
                                                   MULTIPLIED BY THE CONSUMPTION CONSTANT C.  THE RESULT, ZG,
      DO 27 J=1,MM                                 IS USED TO ADJUST THE ORIGINAL SALES FIGURES FOR EACH CENTRE.
   27 A(J)=A(J)*ZG
   30 CONTINUE
C
C
      IF(C)40,40,70                                IF A VALUE FOR THE CONSUMPTION CONSTANT IS SPECIFIED
```

`40 SUM1=0.0`	THE FOLLOWING STEPS ARE OMITTED. OTHERWISE THE CONSTANT IS CALCULATED WITHIN THE PROGRAM AS FOLLOWS. THE PRODUCTS OF INCOME AND POPULATION FOR EACH ZONE I ARE SUMMED AS ARE THE RETAIL SALES FOR EACH CENTRE J. C IS DETERMINED BY DIVIDING THIS LATTER SUM BY THE FORMER TOTAL.
`DO 50 I=1,N`	
`50 SUM1=SUM1+Y(I)*P(I)`	
`SUM2=0.0`	
`DO 60 J=1,M`	
`60 SUM2=SUM2+A(J)`	
`C=SUM2/SUM1`	
`70 DO 80 I=1,N`	TOTAL RETAIL SPENDING IS DETERMINED FOR EACH ZONE I BY USING EITHER THE SPECIFIED OR THE CALCULATED CONSTANT VALUE.
`80 YC(I)=Y(I)*C*P(I)`	
`C`	
`IF(NA)120,120,90`	IF A CALIBRATION RUN IS NOT TO BE MADE CONTROL IS TRANSFERRED TO STATEMENT 120.
`90 PRINT 1008`	OTHERWISE, PRINT THE HEADING CALIBRATION RUN.
`PRINT 1009`	SPACING CONTROL.
`PRINT 1010,C`	PRINT THE VALUE OF THE CONSUMPTION CONSTANT.
`PRINT 1011,AST`	PRINT THE AVERAGE TRIP LENGTH.
`PRINT 1009`	SPACING CONTROL.
`PRINT 1012`	PRINT THE HEADING PARAMETERS.
`PRINT 1013`	PRINT THE HEADINGS FOR THE CALIBRATION RUN OUTPUT.
`READ 1014,AL1,ALI,IAL,ALAM1,ALAMI,ILAM`	READ THE CALIBRATION PARAMETER CARD.
`K=0.0`	
`ALPHA=AL1`	THE PARAMETER ALPHA IS ASSIGNED AN INITIAL VALUE.
`DO 105 IP=1,IAL`	THE NUMBER OF ALPHA INCREMENTS TO BE USED IN THE CALIBRATION RUN IS SPECIFIED.
`LAMBDA=ALAM1`	THE PARAMETER LAMBDA IS ASSIGNED AN INITIAL VALUE.
`ALPHA=ALPHA+ALI`	THE VALUE OF ALPHA IS INCREASED INCREMENTALLY.
`DO 105 JP=1,ILAM`	THE NUMBER OF LAMBDA INCREMENTS TO BE USED IN THE CALIBRATION RUN IS SPECIFIED.
`LAMBDA=LAMBDA+ALAMI`	THE VALUE OF LAMBDA IS INCREASED INCREMENTALLY.
`CALL CALC`	SYNTHESIZED SALES ARE CALCULATED BY THE CALC SUBROUTINE.
`CALL DIFFSQ`	THE SUM OF THE SQUARED DIFFERENCES BETWEEN ACTUAL AND SYNTHESIZED SALES IS CALCULATED BY THE DIFFSQ SUBROUTINE.
`CALL CORR`	THE DEGREE OF CORRELATION BETWEEN ACTUAL AND SYNTHESIZED SALES IS CALCULATED BY THE CORR SUBROUTINE.

`SUM4=0.0`	
`SUM5=0.0`	
`DO 104 J=1,M`	THE PRODUCTS OF SYNTHESIZED SALES FROM I TO J AND THE DISTANCES FROM I TO J ARE SUMMED.
`DO 104 I=1,N`	
`SUM4=SUM4+(S(I,J)*D(I,J))`	
`104 SUM5=SUM5+S(I,J)`	THE SYNTHESIZED SALES FROM I TO J ARE ALSO SUMMED.
`ASTL=SUM4/SUM5`	THE FIRST SUM IS DIVIDED BY THE SECOND SUM TO YIELD AN AVERAGE TRIP LENGTH.
`PRINT 1015,K,DSQ,R,ASTL,ALPHA,LAMBDA`	THE RESULTS OF THE ENTIRE SEQUENCE OF PRECEDING OPERATIONS ARE PRINTED FOR EACH ITERATION SPECIFIED.
`105 CONTINUE`	
`PRINT 1016`	PRINT THE HEADING COMPARISON OF ACTUAL AND SYNTHESIZED SALES.
`PRINT 1009`	SPACING CONTROL.
`K=0.0`	AN IDENTICAL ITERATIVE PROCEDURE TO THAT OUTLINED ABOVE IS EMPLOYED TO DETERMINE THE SYNTHESIZED SALES ASSOCIATED WITH EACH PAIR OF PARAMETER VALUES SPECIFIED IN THE CALIBRATION RUN.
`ALPHA=AL1`	
`DO 107 IP=1,IAL`	
`LAMBDA=ALAM1`	
`ALPHA=ALPHA+ALI`	
`DO 107 JP=1,ILAM`	
`LAMBDA=LAMBDA+ALAMI`	
`CALL CALC`	SYNTHESIZED SALES ARE AGAIN CALCULATED BY THE CALC SUBROUTINE.
`K=K+1.0`	SUCCESSIVE ITERATIONS ARE AGAIN NUMBERED FOR EASY REFERENCE.
`PRINT 1017,K`	THE ACTUAL ITERATION NUMBER IS PRINTED.
`PRINT 1018`	THE HEADING FOR THE COMPARISON OF SALES OUTPUT IS PRINTED.
`PRINT 1019,(J,A(J),T(J),J=1,M)`	ACTUAL AND SYNTHESIZED SALES FOR EACH CENTRE ARE PRINTED FOR EACH ITERATION SPECIFIED.
`107 CONTINUE`	
`PRINT 1020`	THE PRINTER SKIPS TO A NEW PAGE ONCE THE CALIBRATION RUN IS TERMINATED.
`120 CONTINUE`	
`C`	
`C`	

`IF(NB)130,130,125`	IF A STUDY YEAR SIMULATION RUN IS NOT TO BE MADE, CONTROL IS TRANSFERRED TO STATEMENT 130.
`125 READ 1021,ALPHA,LAMBDA`	OTHERWISE, READ THE PARAMETER SPECIFICATION CARD.
`IF(ALPHA)130,130,127`	IF ALPHA IS NOT SPECIFIED, CONTROL PASSES TO STATEMENT 130.
`127 PRINT 1022`	THE HEADING STUDY YEAR SIMULATION RUN IS PRINTED.
`CALL CALC`	SYNTHESIZED SALES ARE DETERMINED BY THE CALC SUBROUTINE.
`GO TO 145`	THE STUDY YEAR SIMULATION RUN PROCEDURE IS CONTINUED AT STATEMENT 145.
`130 CONTINUE`	
`C`	
`C`	
`IF(NC)190,190,135`	IF A PROJECTION RUN IS NOT SPECIFIED, CONTROL PASSES TO STATEMENT 190.
`135 READ 1021,ALPHA,LAMBDA`	OTHERWISE, THE PARAMETER SPECIFICATION CARD IS READ.
`IF(ALPHA)190,190,137`	IF ALPHA IS NOT SPECIFIED, CONTROL IS AGAIN TRANSFERRED TO STATEMENT 190.
`137 PRINT 1023`	THE HEADING PROJECTION RUN IS PRINTED.
`READ 1004,(PB(I),I=1,N)`	READ THE BASE YEAR POPULATION DATA FOR EACH ZONE I.
`READ 1007,(YB(I),I=1,N)`	READ THE BASE YEAR INCOME DATA FOR EACH ZONE I.
`XE=NE`	THE INDICATOR NE IS SPECIFIED AS A REAL NUMBER.
`DO 138 I=1,N`	
`YBC(I)=YB(I)*C*PB(I)`	BASE YEAR ZONAL RETAIL SPENDING IS CALCULATED AS THE PRODUCT OF INCOME TIMES POPULATION TIMES THE CONSUMPTION CONSTANT.
`YDC(I)=YC(I)-YBC(I)`	THE TOTAL INCREASE IN ZONAL RETAIL SPENDING IS CALCULATED BY SUBTRACTING BASE YEAR FIGURES FROM THOSE OF THE DESIGN YEAR.
`YC(I)=YC(I)-YDC(I)`	TOTAL ZONAL RETAIL SPENDING IS DETERMINED FOR THE FIRST YEAR.
`YDC(I)=YDC(I)/XE`	THE OVERALL INCREASE IN RETAIL SPENDING IS DIVIDED BY THE NUMBER OF TIME PERIODS SPECIFIED BY THE INDICATOR NE.
`138 CONTINUE`	
`DO 139 I=1,N`	
`YYB(I)=Y(I)-YB(I)`	AVERAGE ZONAL HOUSEHOLD INCOME IS SIMILARLY TREATED. BASE YEAR FIGURES ARE SUBTRACTED FROM THOSE OF THE DESIGN YEAR TO DETERMINE THE OVERALL INCREASE DURING THE PROJECTION PERIOD.
`YYB(I)=YYB(I)/XE`	THIS INCREASE IS DIVIDED BY THE VALUE ASSIGNED TO THE INDICATOR NE.
`139 CONTINUE`	
`K=0`	
`140 CONTINUE`	
`K=K+1.0`	OUTPUT IS GENERATED FOR EACH TIME SPAN SPECIFIED IN THE PROJECTION PERIOD.

FROM 181

DO 142 I=1,N	TO STATEMENT 190.
YB(I)=YB(I)+YYB(I)	WITH EACH ITERATION, BASE YEAR ZONAL INCOME AND TOTAL RETAIL SPENDING ARE INCREASED BY AN APPROXIMATELY EQUAL INCREMENT.
142 YC(I)=YC(I)+YDC(I)	
145 CALL CALC	SYNTHESIZED SALES ARE CALCULATED BY THE CALC SUBROUTINE.
CALL DIFFSQ	THE SUM OF THE SQUARED DIFFERENCES BETWEEN ACTUAL AND SYNTHESIZED SALES IS CALCULATED BY THE DIFFSQ SUBROUTINE.
PRINT 1024,DSQ	THE SUM OF THE SQUARED DIFFERENCES IS PRINTED.
T1=0.0	SUMMARY SITE VARIABLES ARE INITIALIZED.
T2=0.0	
T3=0.0	
DO 147 J=1,M	
T1=T1+FS(J)	TOTAL FLOORSPACES FOR ALL CENTRES ARE SUMMED.
T2=T2+FOOD(J)	FOOD FLOORSPACES FOR ALL CENTRES ARE SUMMED.
T3=T3+DSTM(J)	DSTM FLOORSPACES FOR ALL CENTRES ARE SUMMED.
147 CONTINUE	
IF(NC)148,148,152	IF A PROJECTION RUN IS TO BE MADE, CONTROL PASSES TO STATEMENT 152.
148 DO 150 J=1,M	IF A STUDY YEAR SIMULATION RUN IS TO BE MADE, THE CUSTOMER FLOW FROM EACH ZONE I TO EACH CENTRE J IS DETERMINED BY DIVIDING THE CASH FLOWS FROM EACH ZONE I TO EACH CENTRE J BY THE CORRESPONDING AVERAGE ZONAL HOUSEHOLD INCOMES.
DO 150 I=1,N	
CD(I,J)=S(I,J)/(Y(I)*C)	
150 CONTINUE	
GO TO 160	
152 DO 155 J=1,M	IF A PROJECTION RUN IS TO BE MADE, CUSTOMER FLOWS FROM I TO J ARE DETERMINED FOR EACH TIME PERIOD SPECIFIED BY DIVIDING THE CASH FLOWS FROM I TO J BY CORRESPONDING AVERAGE ZONAL HOUSEHOLD INCOME VALUES ADJUSTED OVER TIME.
DO 155 I=1,N	
155 CD(I,J)=S(I,J)/(YB(I)*C)	
160 CONTINUE	
DO 162 J=1,M	THE NUMBERS OF CONSUMERS OR HOUSEHOLDS TRAVELLING FROM ALL ZONES TO EACH CENTRE ARE SUMMED. THIS YIELDS THE TOTAL NUMBER OF CUSTOMERS IN THE STUDY AREA PATRONIZING EACH CENTRE.
TMKT(J)=0.0	
DO 162 I=1,N	
TMKT(J)=TMKT(J)+CD(I,J)	

```
162 CONTINUE
    DO 163 J=1,M                    THE DISTANCES FROM EACH ZONE I TO EACH CENTRE J ARE WEIGHTED
    DO 163 I=1,N                    BY THE NUMBER OF CONSUMERS OR HOUSEHOLDS IN EACH ZONE I
                                    SHOPPING AT EACH CENTRE J.
    AVT(I,J)=D(I,J)*CD(I,J)
163 CONTINUE
    DO 164 J=1,M                    THESE WEIGHTED VALUES ARE SUMMED BY CENTRE OVER ALL ZONES.
    SUMTL(J)=0.C                    THIS SUM IS THEN DIVIDED BY THE TOTAL NUMBER OF CUSTOMERS
                                    ATTRACTED TO EACH CENTRE TO PROVIDE AN AVERAGE TRIP LENGTH
                                    TO EACH CENTRE FROM ALL ZONES WEIGHTED BY CUSTOMER FLOW.
    DO 164 I=1,N
    SUMTL(J)=SUMTL(J)+AVT(I,J)
    SUMT(J)=SUMTL(J)/TMKT(J)
164 CCNTINUE
    TL=0.0
    DO 165 J=1,M                    THE AVERAGE TRIP LENGTHS THUS CALCULATED FOR EACH CENTRE ARE
    TL=TL+SUMT(J)                   SUMMED AND DIVIDED BY THE NUMBER OF CENTRES BEING CONSIDERED
                                    TO ARRIVE AT AN AVERAGE WEIGHTED TRIP LENGTH FOR THE ENTIRE
                                    STUDY AREA.
    T12=TL/M
165 CONTINUE
    T4=0.0                          REMAINING SUMMARY SITE VARIABLES ARE INITIALIZED.
    T5=0.0
    T6=0.0
    T7=0.0
    T8=0.0
    T9=0.0
    T10=0.0
    T11=0.0
    DO 167 J=1,M
    T4=T4+TMKT(J)                   TOTAL CUSTOMERS SHOPPING AT ALL CENTRES ARE SUMMED.
    T5=T5+T(J)                      SYNTHESIZED SALES FOR ALL CENTRES ARE SUMMED.
    T6=T6+A(J)                      ACTUAL ESTIMATED SALES GENERATED BY ALL CENTRES ARE SUMMED.
    RATIO(J)=T(J)/FS(J)             SYNTHESIZED SALES PER SQUARE FOOT ARE CALCULATED FOR EACH
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      ACTRAT(J)=A(J)/FS(J)                                ACTUAL ESTIMATED SALES PER SQUARE FOOT ARE SIMILARLY
                                                          CALCULATED FOR EACH CENTRE.
      T8=T6/T1                                            AN AVERAGE ACTUAL ESTIMATED SALES PER SQUARE FOOT FIGURE IS
                                                          OBTAINED BY DIVIDING TOTAL ACTUAL SALES BY TOTAL FLOORSPACE.
  167 CONTINUE

      DO 170 J=1,M

      FRTMK(J)=TMKT(J)/T4*100.0                           THE CUSTOMERS ATTRACTED TO EACH CENTRE J ARE CONVERTED INTO
                                                          PERCENTAGE TERMS.
      T9=T9+FRTMK(J)                                      THE CORRESPONDING PERCENTAGE VALUES ARE SUMMED.

      SLSMK(J)=T(J)/T5*100.0                              THE SYNTHESIZED SALES GENERATED BY EACH CENTRE ARE CONVERTED
                                                          INTO PERCENTAGE TERMS.
      T10=T10+SLSMK(J)                                    THE CORRESPONDING PERCENTAGES ARE SUMMED.

      ASLSMK(J)=A(J)/T6*1CC.0                             THE ACTUAL ESTIMATED SALES GENERATED BY EACH CENTRE ARE
                                                          CONVERTED INTO PERCENTAGE TERMS.
      T11=T11+ASLSMK(J)                                   THE CORRESPONDING PERCENTAGES ARE SUMMED.

  170 CONTINUE

      PRINT 1025                                          PRINT THE HEADING SUMMARY SITE INFORMATION.

      PRINT 1026                                          PRINT THE CORRESPONDING SUBHEADINGS.

      PRINT 1027                                          SPACING CONTROL.

      PRINT 1028,(J,FS(J),FOOD(J),DSTM(J),SUMT(J),TMKT(J),  PRINT THE SUMMARY SITE OUTPUT TABLE.
     1T(J),A(J),RATIC(J),ACTRAT(J),FRTMK(J),SLSMK(J),
     2ASLSMK(J),J=1,M)

      PRINT 1029,T1,T2,T3,T12,T4,T5,T6,T7,T8,T9,T10,T11   PRINT SUMMARY SITE TOTALS.

      PRINT 1020                                          SKIP TO A NEW PAGE.

      PRINT 1030                                          PRINT HEADING ZONAL RETAIL SPENDING.

      PRINT 1027                                          SPACING CONTROL.

      PRINT 1031,(I,YC(I),I=1,N)                          PRINT THE TOTAL AVAILABLE RETAIL SPENDING FOR EACH ZONE I.

      PRINT 1009                                          SPACING CONTROL.

      PRINT 1010,C                                        PRINT THE CONSUMPTION CONSTANT SPECIFIED.

      PRINT 1009                                          SPACING CONTROL.

      PRINT 1032                                          PRINT THE HEADING PARAMETERS.

      PRINT 1033,ALPHA,LAMBDA                             PRINT AND IDENTIFY THE PARAMETER VALUES SPECIFIED.

      MA=1
```

`MB=12`	THESE CARDS SPECIFY THE DIMENSIONS OF THE CASH FLOW MATRIX TO BE PRINTED. IF THE NUMBER OF CENTRES IS LESS THAN 12, MB MUST CORRESPOND TO THE ACTUAL NUMBER OF CENTRES. OTHERWISE NO CHANGE IS NECESSARY.
`172 CONTINUE`	
`PRINT 1034,(J,J=MA,MB)`	PRINT THE HEADING CASH FLOWS TO.
`PRINT 1027`	SPACING CONTROL.
`DO 173 I=1,N`	
`173 PRINT 1035,I,(S(I,J),J=MA,MB)`	CASH FLOWS FROM EACH ZONE I TO EACH CENTRE J ARE PRINTED IN A MATRIX FORMAT.
`IF(MB.EQ.M)GO TO 175`	IF THE VALUE FOR MB COINCIDES WITH THE NUMBER OF CENTRES THE PROCEDURE IS TERMINATED. OTHERWISE, THE MATRIX IS CONTINUED ON SUBSEQUENT PAGES UNTIL ALL CENTRES ARE ACCOUNTED FOR.
`MA=MA+12`	
`MB=MB+12`	
`IF(MB.GT.M)MB=M`	
`GO TO 172`	CONTROL IS RETURNED TO STATEMENT 172.
`175 CONTINUE`	
`MA=1`	THESE CARDS SPECIFY THE DIMENSIONS OF THE CUSTOMER FLOW MATRIX. IF THE NUMBER OF CENTRES IS LESS THAN 15, MB MUST CORRESPOND TO THE ACTUAL NUMBER OF CENTRES. OTHERWISE, NO CHANGE IS REQUIRED.
`MB=15`	
`176 CONTINUE`	
`PRINT 1036,(J,J=MA,MB)`	PRINT THE HEADING CUSTOMER FLOWS TO.
`PRINT 1027`	SPACING CONTROL.
`DO 177 I=1,N`	
`177 PRINT 1037,I,(CD(I,J),J=MA,MB)`	CUSTOMER FLOWS FROM EACH ZONE I TO EACH CENTRE J ARE PRINTED IN A MATRIX FORMAT.
`IF(MB.EQ.M)GO TO 179`	IF THE VALUE OF MB COINCIDES WITH THE NUMBER OF CENTRES, THE PROCEDURE IS TERMINATED. OTHERWISE THE MATRIX IS CONTINUED ON SUBSEQUENT PAGES UNTIL ALL CENTRES ARE ACCOUNTED FOR.
`MA=MA+15`	
`MB=MB+15`	
`IF(MB.GT.M)MB=M`	
`GO TO 176`	CONTROL IS RETURNED TO STATEMENT 176.
`179 CONTINUE`	
`PRINT 1020`	SKIP TO NEW PAGE.
`IF(NC)190,190,181`	IF A PROJECTION RUN IS BEING MADE, CONTROL IS RETURNED TO STATEMENT 140 AND THE PRECEDING SEQUENCE OF OPERATIONS IS REPEATED FOR THE NEXT TIME PERIOD.
`181 GC TC 140`	

TO 140

```
 192 CONTINUE                                    OTHERWISE CONTROL IS RETURNED TO THE BEGINNING OF THE PROGRAM
                                                 ALLOWING ADDITIONAL DATA DECKS TO BE READ.
     GC TC 1

1000 FORMAT (2I3)                                THE FOLLOWING CARDS, NUMBERED 1000 TO 1037, SPECIFY THE
                                                 FORMATS ASSOCIATED WITH ALL PRINT STATEMENTS FOUND IN THE
1001 FORMAT (4I2,F8.6,3I2)                       BODY OF THE PROGRAM.

1002 FORMAT (F8.2)

1003 FORMAT (12F6.0)

1004 FORMAT (8F10.0)

1005 FORMAT (7F10.0)

1006 FORMAT (2F10.0)

1007 FORMAT (10F8.2)

1008 FORMAT ('1',1X, 'CALIBRATION RUN')

1009 FORMAT ('0')

1010 FORMAT ('0',1X, 'CONSUMPTICN CONSTANT',3X,F9.6)

1011 FORMAT ('0',1X, 'INPUT TRIP LENGTH',F8.2)

1012 FORMAT (' ',58X,'PARAMETERS')

1013 FORMAT ('C',9X,'DIFF SQ',11X,'CORR',7X,'TRIP LENGTH',

    14X,'ALPHA',9X,'LAMBDA')

1014 FORMAT (2(2F9.6,I2))

1015 FORMAT ('0',I3,F15.2,5X,F10.6,5X,F8.2,5X,F9.6,5X,F9.6)

1016 FORMAT ('1',7X,'COMPARISON OF ACTUAL AND SYNTHESIZED SALES')

1017 FORMAT ('0',10X,I3)

1018 FORMAT ('0',9X,'SITE',2X,'INPUT SALES',5X,'SYNTHESIZED SALES')

1019 FORMAT (' ',9X,I2,4X,F10.0,9X,F10.0)

1020 FORMAT ('1')

1021 FORMAT (2F9.6)

1022 FORMAT ('1',1X, 'STUCY YEAR SIMULATION RUN')

1023 FORMAT ('1',1X, 'PROJECTION RUN')

1024 FCRMAT ('0',1X,'DIFF SQ',2X,F15.2)
```

```
1025 FORMAT ('0',50X, 'SUMMARY SITE INFORMATION')
1026 FORMAT ('0', 'SITE',4X,'SIZE',9X,'FCCD',7X,'DSTM',7X,
    1'AVTL',4X,'CUST',5X,'SYN SALES',4X,'ACT SALES',5X,
    2'CS/FT',5X,'AS/FT',5X,'HH SH',5X,'CA$SH',5X,'AC$SH')
1027 FORMAT (' ')
1028 FORMAT (' ',I2,2X,F10.0,2X,F10.0,2X,F10.0,3X,F6.2,2X,
    1F7.0,2X,F11.0,2X,F11.0,2X,F8.2,2X,F8.2,2X,F8.2,2X,
    2F8.2,2X,F8.2)
1029 FORMAT ('0','TOTAL',F9.0,2X,F10.0,2X,F10.0,3X,F6.2,
    12X,F7.0,2X,F11.0,2X,F11.0,2X,F8.2,2X,F8.2,2X,
    2F8.2,2X,F8.2,2X,F8.2)
1030 FORMAT (' ','ZCNAL RETAIL SPENDING')
1031 FORMAT (' ',3X,I2,4X,F10.0)
1032 FCRMAT ('0',1X,'PARAMETERS')
1033 FORMAT ('0',1X,'ALPHA',3X,F8.4,3X,'LAMBDA',F8.4)
1034 FORMAT ('1',1X, 'CASH FLOWS TO'//4X,12I10)
1035 FORMAT ('0',I2,2X,12F10.0)
1036 FORMAT ('1',1X, 'CUSTOMER FLOWS TO'//4X,15I8)
1037 FORMAT ('0',I2,2X,15F8.0)
 195 CONTINUE
     STOP                                THE PROGRAM IS TERMINATED.
     END
C
C
     SUBRCUTINE CALC                     THIS SUBROUTINE CALCULATES THE SYNTHESIZED SALES GENERATED
                                         AT EACH RETAIL CENTRE J.
C
     CCMMON/AA/A,T,M,N/BB/D,S,ALPHA,LAMBDA,YC
     DIMENSICN A(40),D(70,40),S(70,40),YC(70),SUM3(70),T(40)
```

```
      SUM3(I)=0.0                                     THIS YIELDS THE PROBABILITY OF SHOPPERS TRAVELLING ALONG
                                                      ANY POSSIBLE ZONE-TO-CENTRE COMBINATION.
      DO 200 J=1,M
      S(I,J)=A(J)**ALPHA/EXP(D(I,J)*LAMBDA)
  200 SUM3(I)=SUM3(I)+S(I,J)                          THE RESULTS ARE SUMMED.
      DO 201 J=1,M                                    THE SYNTHESIZED SALES FROM EACH ZONE I TO EACH CENTRE J ARE
                                                      DERIVED BY MULTIPLYING ZONAL RETAIL SPENDING BY THE
                                                      PROBABILITY OF GOING FROM EACH ZONE TO EACH CENTRE.
      T(J)=0.0
      DO 201 I=1,N
      S(I,J)=YC(I)*S(I,J)/SUM3(I)
  201 T(J)=T(J)+S(I,J)                                THE SYNTHESIZED SALES FROM ALL ZONES TO EACH CENTRE J ARE
                                                      SUMMED TO YIELD THE TOTAL SYNTHESIZED SALES AT EACH CENTRE.
      RETURN
      END
C
C
      SUBROUTINE DIFFSQ                               THIS SUBROUTINE CALCULATES THE ABSOLUTE DIFFERENCE BETWEEN
                                                      SYNTHESIZED AND ACTUAL SALES FOR ALL CENTRES.
C
      CCMMON/AA/A,T,M,N/DD/DSQ
      DIMENSION A(40),T(40)
      DSQ1=0.0
      DO 300 J=1,M                                    THE DIFFERENCE IS SQUARED AND THEN DIVIDED BY ONE MILLION TO
                                                      MAKE IT A MORE EASILY MANAGEABLE FIGURE.  THESE RESULTS ARE
                                                      SUMMED FOR ALL CENTRES TO GIVE AN INDICATION OF THE GOODNESS
                                                      OF FIT OBTAINED.
  300 DSQ1=DSQ1+(ABS(A(J)-T(J))**2)
      DSQ=DSQ1/1000C00.C
      RETURN
      END
C
C
      SUBROUTINE CORR                                 THIS SUBROUTINE DETERMINES THE DEGREE OF CORRELATION BETWEEN
                                                      SYNTHESIZED SALES AND ACTUAL ESTIMATED SALES FOR ALL CENTRES.
C
      COMMON/AA/A,T,M,N/CC/R
```

```
      DIMENSION A(40),T(40)
      XM=M
      SUMX=0.0
      SUMY=0.0
      SUMXX=0.0
      SUMYY=0.0
      SUMXY=0.0
      DO 400 J=1,M
      SUMX=SUMX+A(J)                  ACTUAL ESTIMATED SALES FOR ALL CENTRES ARE SUMMED.
      SUMY=SUMY+T(J)                  SYNTHESIZED SALES FOR ALL CENTRES ARE SUMMED.
      SUMXX=SUMXX+A(J)**2             ACTUAL ESTIMATED SALES FOR ALL CENTRES ARE SQUARED AND SUMMED.
      SUMYY=SUMYY+T(J)**2             SYNTHESIZED SALES FOR ALL CENTRES ARE SQUARED AND SUMMED.
  400 SUMXY=SUMXY+(A(J)*T(J))         THE PRODUCTS OF ACTUAL ESTIMATED AND SYNTHESIZED SALES FOR
                                      ALL CENTRES ARE SUMMED.
      XBARX=SUMX/XM                   THE MEAN ACTUAL ESTIMATED SALES IS CALCULATED.
      XBARY=SUMY/XM                   THE MEAN SYNTHESIZED SALES IS CALCULATED.
      R=(SUMXY/XM-(XBARX*XBARY))/     THE COEFFICIENT OF CORRELATION IS CALCULATED USING THE
     1SQRT((SUMXX/XM-XBARX**2)*(SUMYY/XM-XBARY**2))   RESULTS OF THE PRECEDING STEPS.
      RETURN
      END
```

Annotated Selected Bibliography

APPLEBAUM, William (ed.). *Store Location and Development Studies*, Worcester, Mass.: Clark University, 1962.

A reader containing articles which discuss projections of future retail floorspace requirements, the rate of change in retailing and the techniques of mapping urban land use and population data.

BAKER, Geoffery and Bruno FUNARO. *Shopping Centres - Design and Operation*, New York: Reinhold, 1951.

An early but still useful examination of shopping centre design, location, and parking. The determination of future floorspace requirements is not as well covered as are the sections on how retail centres operate.

BERRY, Brian J. L. *Commercial Structure and Commercial Blight*, Chicago: Department of Geography Research Paper No. 85, University of Chicago, 1963.

An important contribution to understanding the spatial structure of shopping in an urban area. Defines causes of blight and decay and how the problems can be tackled through empirical studies.

BERRY, Brian J. L. "The Retail Component of the Urban Model". *Journal of the American Institute of Planners*, Vol. 31, No. 2, May 1965, pp 150-155.

A concise statement of the methods developed in *Commercial Structure and Commercial Blight* to plan for future retail floorspace requirements.

BERRY, Brian J. L. *Geography of Market Centres and Retail Distribution*, Englewood Cliffs, N.J.: Prentice-Hall, 1967.

A review of the approaches to a study of shopping centres by geographers, market analysts, urban planners, and regional

scientists. A very useful source for interpreting reports on shopping centre site potential.

BROWN, Milton P. and Eleanor G. MAY. *Operating Results of Multi-Unit Department Stores*, Cambridge, Mass.: Harvard University Graduate School of Business Administration, Bureau of Business Research Bulletin, 1961.

Relates efficiency and profitability of the suburban branches of downtown department stores.

CARROTHERS, Gerald A. P. "An Historical Review of Gravity and Potential Concepts of Human Interaction". *Journal of the American Institute of Planners*, Vol. 22, No. 2, Spring 1956, pp 94-102.

The application of the spatial interaction concept to analysis of the urban area. A definitive article of special interest to those concerned with gravity potential simulation models of retail location.

CONTROLLERS' CONGRESS. *Merchandising and Operating Results of Department and Specialty Stores*, New York.: National Retail Merchants Association, 1950 to 1968.

A prime source of data for those involved in the planning or renewal of shopping districts. Covers items of cost, sales per square foot of net selling space, and profits.

COX, William E., Jr. "A Commercial Structure Model for Depressed Neighbourhoods". *Journal of Marketing*, Vol. 33, No. 3, July 1969, pp 1-9.

An application of the traditional market analysis techniques to specific centres in the older neighbourhoods of Cleveland. A clear presentation of the methodology employed in ensuring that a neighbourhood retail centre serves the needs of its trade area customers in terms of the number and type of stores represented.

FRIEND, J. K. and W. N. JESSOP. *Local Government and Strategic Choice*, London: Tavistock Publications, 1969.

A review of decision making at the level of a municipal government. Includes several lucid examples of the analysis of the gross uncertainties inherent in the traditional trade area analysis approach to estimating future retail floorspace requirements. Raises the level of understanding of the decision taking process in Coventry, England which has already achieved renown for its far-sightedness in making decisions about its future.

FRIENDLY, Philip M. *A Methodology for Economic Analysis of Retail Commercial Facilities in Urban Renewal Areas*, Vancouver: City Planning Department, Vancouver, 1966.

A useful compendium of the methods of analysis for the retail component of urban renewal studies. Contains an extensive bibliography on retail trade and land use.

GREAT BRITAIN: NATIONAL ECONOMIC DEVELOPMENT OFFICE, *Shopping Models*, London: Her Majesty's Stationery Office, 1970.

A comprehensive and competent review of the methods available for studying the impact of new shopping centres on existing development and of forecasting future shopping space requirements. Most useful in providing an understanding of the computer oriented gravity-potential simulation models employed increasingly in Great Britain, France and Scandinavia.

GRUEN, Victor and Larry SMITH. *Shopping Towns: U.S.A.*, New York: Reinhold, 1960.

One of the best sources of information on all aspects of shopping centre location, planning, operation and design. Covers market analysis clearly and concisely. Along with the Nelson book mentioned below, a necessary item on the planning bookshelf.

HAYES, Martyn Cordey. *Retail Location Models*, London: Centre for Environmental Studies, C.E.S. Working Paper No. 16, 1968.

A truly comprehensive survey of the methods, both current and potential, which can be applied to a study of the problems of retail location, including their advantages and shortcomings.

HORWOOD, Edgar M. "Public Policy and the Outlying Shopping Centre". *Journal of the American Institute of Planners*, Vol. 24, No. 4, Fall 1958, pp 215-222.

Presents the case for careful control by the municipality of the size and spacing of shopping centres in a metropolitan area.

HOYT, Homer. *The Dollars and Cents of Shopping Centres*, Washington, D.C.: Urban Land Institute, 1972.

A basic guide to the measurement of retail space requirements, costs of development and operation, rental arrangements, the mix of stores in a centre and the essential conversion tables required by the planner and market analyst in any study of retail centres.

HUFF, David L. "A Probabilistic Analysis of Shopping Centre Trade Areas". *Land Economics*, Vol. 39, No. 1, February 1963, pp 81-90.

The application of probability theory to the determination of market potential using geographic techniques.

HUFF, David L. and Larry BLUE. *A Programmed Solution to Estimating Retail Sales Potentials*, Lawrence, Kansas: Centre for Regional

Studies, The University of Kansas, 1964.

A program in Fortran IV of the Huff formulation of the retail gravity-potential model. Includes full instruction, data for testing, application and interpretation.

KELLY, Eugene J. *Shopping Centres - Locating Controlled Regional Centres,* New York: ENO Foundation for Highway Traffic Control, 1956.

A general reference on the factors influencing location of regional centres.

KENDRICK, J. G. "Retailing in Canada". *The Canadian Marketer,* Winter 1969-70, pp 11-15.

A useful review of retail development in Canada by the President of Zellers. Provides a comprehensive listing of future trends in Canadian retailing.

LAKSHMANAN, T. R. and Walter G. HANSEN. "A Retail Market Potential Model". *Journal of the American Institute of Planners,* Vol. 31, No. 2, May 1965, pp 134-143.

A report on the use of the gravity-potential concept in the analysis of retail location. This article has been the basis for much of the subsequent study of retail location in Great Britain and Scandinavia.

McNAIR, Malcolm P. *Operating Results of Department and Specialty Stores,* Cambridge, Mass.: Harvard University Graduate School of Business Administration, Business Research Bulletins, 1969.

Similar to the NRMA publication mentioned above except that results are stated in terms of gross enclosed space rather than in sales per square foot of net selling space.

MOYER, M. S. and G. SNYDER. *Trends in Canadian Marketing,* Ottawa: Dominion Bureau of Statistics. 1961 Census Monograph Programme, 1967.

A detailed analysis of trends in retailing in Canada up to 1961.

NELSON, Richard L. *The Selection of Retail Locations,* New York: F. W. Dodge, 1958.

A book for the planners bookshelf. Excellent treatment of most aspects of retail location analysis and trade area surveys. A great deal of general and interesting detailed information about location studies and consumer behaviour.

PLANNING AND TRANSPORT RESEARCH AND COMPUTATION COMPANY LIMITED. *Shopping Models, Parts I and II,* London: Planning and

Transport Research and Computation Company Limited, Seminar Proceedings, October 1968.

The papers and proceedings of a conference on shopping models sponsored by the PTRCCO in October 1968. Papers were read and discussed by invited participants from government, business, universities, planning agencies and private consultants. The contributors were from Great Britain, Denmark and France. Important material for those concerned in detail with the study of the impact of suburban shopping centres on existing or planned retail facilities.

SIMMONS, James W. *The Changing Pattern of Retail Location*, Chicago: University of Chicago Press, 1964.

A companion book to *Commercial Structure and Commercial Blight*. Details the changes in spatial structure of retail locations in Chicago over an extended period of time.

SIMMONS, James W. *Toronto's Changing Retail Complex*, Chicago: University of Chicago Department of Geography Research Paper No. 104, University of Chicago, 1966.

An application of the Berry analysis in a Canadian context. Useful methodology and analysis.

STEDMAN, Gordon H. "The Rise of Shopping Centres". *Journal of Retailing*, Spring 1955, pp 11-26.

Traces the development of shopping centres from their inception in the 1920's to their current state of development in the 1950's. Much of this material is also covered in the Gruen and Smith book.

STERNLIEB, George. *The Future of the Downtown Department Store*, Cambridge, Mass.: Harvard University Press, 1962.

An analysis of the role of department stores in the downtown of American cities and the strategies which have been employed in suburban shopping centre development.

THOMPSON, Donald L. "Future Directions in Retail Area Research". *Economic Geography*, Vol. 42, No. 1, January 1966, pp 1-18.

A concise statement of the development of trade area analysis and marketing models. Includes a useful discussion of the limitations of current methodologies and an exploration of new areas for research in retail location.

TRI-COUNTY REGIONAL PLANNING COMMISSION. *Shopping Centre Effects on Central Business Districts*, Akron, Ohio: Regional Planning Study No. 37, Tri-County Regional Planning Commission (Medina-Summit-Portage), October 1965.

A partial analysis of the effects of suburban shopping centres on downtown areas. Measures trends from 1950-1963 in the distribution of retail sales in Akron and examines the results of a survey of consumer attitudes and preferences for shopping centres as opposed to central business districts.

UNIVERSITY OF MANCHESTER. *Regional Shopping Centres: A Planning Report on North West England, Part I and Part II (A Retail Shopping Model)*, Manchester: Department of Town and Country Planning, University of Manchester, 1964 and 1966.

The two volumes are the results of an investigation into a proposal for a regional shopping centre at Haydock, Lancashire which lies between Manchester and Liverpool. These large-scale studies undertaken in Manchester provide information on the need for the centre, its desirability, its potential profitability and its impact on existing shopping centres over a very wide region in the Midlands. The investigation also touched on broader issues, such as the relation of the selected site to future proposed and possible changes in patterns of population distribution, road and rail networks and on urban and regional planning and development in general. The second report presents the results of the use of the gravity-potential model to an analysis of the same problem but using the emerging techniques of computer simulation. These studies are considered to be very important to anyone concerned with evaluating the impact of retail development on existing centres because they bridge the gap between the approaches of the trade area analyst and the spatial interaction modeller.

URBAN LAND INSTITUTE. *The Community Builders Handbook*, Washington, D.C.: Urban Land Institute, 1969.

A useful reference book for planners on all aspects of building the urban community from housing to industrial parks. An extensive section on all the studies employed in shopping centre development. Detailed and authoritative.

General Bibliography

ABERGARD, E. "Current Work of the Institute for Centre Planning". *Shopping Models Part I,* London: Planning and Transport Research and Computation Company Limited, October 1969.

ABERGARD, E., P. A. OLSEN and J. ALLPASS. *The Interaction Between Retailing and the Urban Structure,* Copenhagen: Institute for Centre Planning, 1968.

ALLPASS, J. et al. "Changes in the Structure of Urban Centres". *Journal of the American Institute of Planners,* Vol. 34, No. 3, May 1968.

AMBROSE, P. J. "An Analysis of Intra-urban Shopping Patterns". *Town Planning Review,* Vol. 38, No. 4, January 1968.

ANDREWS, Howard F. "A Note on Forecasting Shopping Demand". *Journal of the Town Planning Institute,* Vol. 53, No. 8, September/October 1967, pp 352-354.

APPLEBAUM, William (ed.). *Store Location and Development Studies,* Worcester, Mass.: Clark University, 1962.

APPLEBAUM, William. "Methods for Determining Store Trade Areas, Market Penetration and Potential Sales". *Journal of Marketing Research,* Vol. 3, No. 2, May 1966a, pp 127-141.

APPLEBAUM, William. "Guidelines for a Store-location Strategy Study". *Journal of Marketing,* Vol. 30, No. 4, October 1966b, pp 42-45.

APPLEBAUM, William. *Guide to Store Location Research,* Reading: Addison-Wesley, 1968.

APPLEBAUM, William. *Shopping Center Strategy,* New York: International Council of Shopping Centers, 1970.

BACON, R. W. *The Cowley Shopping Centre,* London: Her Majesty's Stationery Office, 1968.

BAKER, Geoffery and Bruno FUNARO. *Shopping Centres - Design and Operation,* New York: Reinhold, 1951.

BASKIN, C. *The Central Places of Southern Germany,* Englewood Cliffs: Prentice-Hall, 1966.

BATTY, Michael. "Exploratory Calibration of a Retail Location Model Using Search by Golden Section". *Environment and Planning,* Vol. 3, No. 4, 1971, pp 411-432.

BATTY, Michael. "Spatial Entropy". *Geographical Analysis,* Vol. VI, No. 1, January 1974, pp 1-31.

BATTY, Michael and S. MACKIE. "The Calibration of Gravity, Entropy, and Related Models of Spatial Interaction". *Environment and Planning,* Vol. 4, No. 2, 1972, pp 205-233.

BATTY, Michael and Arild SAETHER. "A Note on the Design of Shopping Models". *Journal of the Royal Town Planning Institute,* Vol. 58, No. 7, July/August 1972, pp 303-306.

BERRY, Brian J. L. *Commercial Structure and Commercial Blight,* Chicago: Department of Geography Research Paper No. 85, University of Chicago, 1963.

BERRY, Brian J. L. "The Retail Component of the Urban Model". *Journal of the American Institute of Planners,* Vol. 31, No. 2, May 1965, pp 150-155.

BERRY, Brian J. L. *Geography of Market Centers and Retail Distribution,* Englewood Cliffs, N.J.: Prentice-Hall, 1967.

BERRY, Brian J. L., H. G. BARNUM and R. J. TENNANT. "Retail Location and Consumer Behavior". *Papers and Proceedings of the Regional Science Association,* Vol. 9, 1962, pp 65-106.

BERRY, Leonard L. "The Components of Department Store Image: A Theoretical and Empirical Analysis". *Journal of Retailing,* Vol. 45, No. 1, Spring 1969, pp 3-20.

BETTMAN, James R. and J. Morgan JONES. "Formal Models of Consumer Behavior: A Conceptual Overview". *Journal of Business,* Vol. 45, No. 4, October 1972, pp 544-562.

BISHOP, Willard R. and Earl H. BROWN. "An Analysis of Spatial Shopping Behavior". *Journal of Retailing,* Vol. 45, No. 2, Summer 1969, pp 23-30.

BROOKSBANK, J. S., J. LILLYWHITE and A. J. SHELTON. "West Yorkshire Study". *Official Architecture and Planning,* Vol. 33, No. 1, January 1970, pp 30-34.

BROWN, Milton P. and Eleanor G. MAY. *Operating Results of Multi-Unit Department Stores,* Cambridge, Mass.: Harvard University Graduate School of Business Administration, Bureau of Business Research Bulletin, 1961.

BRUNNER, James A. and John L. MASON. "The Influence of Driving Time upon Shopping Center Preference". *Journal of Marketing,* Vol. 32, No. 2, April 1968, pp 57-61.

BUCKLIN, Louis P. "Testing Propensities to Shop". *Journal of Marketing,* Vol. 30, No. 1, January 1966, pp 22-27.

BUCKLIN, Louis P. "The Concept of Mass in Intra-urban Shopping". *Journal of Marketing,* Vol. 31, No. 4, Part 1, October 1967, pp 37-42.

BUCKLIN, Louis P. "Trade Area Boundaries: Some Issues in Theory and Methodology". *Journal of Marketing Research,* Vol. 8, No. 1, February 1971, pp 30-37.

CARROTHERS, Gerald A. P. "An Historical Review of the Gravity and Potential Concepts of Human Interaction". *Journal of the American Institute of Planners,* Vol. 22, No. 2, May 1956, pp 94-102.

CLAUS, R. James. "Appraising the Potential Volume of Sales at a Shopping Centre Site". *Appraisal Institute Magazine,* Vol. 16, Book 3, Winter 1971-72, pp 2-22.

CHRISTALLER, W. *Die zentralen Orte in Suddeutschland,* Jena: Custav Fisher, 1933.

CONTROLLERS' CONGRESS. *Merchandising and Operating Results of Department and Specialty Stores,* New York: National Retail Merchants Association, 1950-1968.

COPELAND, Melvin T. *Principles of Merchandising,* Chicago: A. W. Shaw, 1922.

COX, William E., Jr. "A Commercial Structure Model for Depressed Neighbourhoods". *Journal of Marketing,* Vol. 33, No. 3, July 1969, pp 1-9.

COX, William E., Jr. and Ernest F. COOKE. "Other Dimensions Involved in Shopping Center Preference". *Journal of Marketing,* Vol. 34, No. 4, October 1970, pp 12-17.

CRESS, P., P. DIRKSEN and J. W. GRAHAM. *Fortran IV with Watfor and Watfiv,* Englewood Cliffs: Prentice-Hall, 1970.

CULLEN, Ian G. *A Mathematical Study of Retail Impact,* London: University College, Department of Town Planning, Discussion Paper Series No. 3, January 1969.

CURRY, L. "A Spatial Analysis of Gravity Flows". *Regional Studies,* Vol. 6, No. 2, June 1972, pp 131-147.

DAVIES, R. L. "Variable Relationships in Central Place and Retail Potential Models". *Regional Studies,* Vol. 4, No. 1, 1970, pp 49-61.

DAVIES, R. L. and B. J. STYLES. *Gravity Models in Town Planning,* Coventry: Lanchester College of Technology, October 1969.

DECKER, W. S. (ed.). *Emerging Concepts in Marketing,* American Marketing Association, 1963.

FARLEY, John U. and L. Winston RING. "An Empirical Test of the Howard-Sheth Model of Buyer Behavior". *Journal of Marketing Research,* Vol. 7, No. 4, November 1970, pp 427-438.

FRIEND, J. K. and W. N. JESSOP. *Local Government and Strategic Choice,* London: Tavistock Publications, 1969.

FRIENDLY, Philip M. *A Methodology for Economic Analysis of Retail Commercial Facilities in Urban Renewal Areas,* Vancouver: City Planning Department, Vancouver, 1966.

GIBSON, M. and M. PULLEN. "Retail Turnover in the East Midlands: A Regional Application of a Gravity Model". *Regional Studies,* Vol. 6, No. 2, June 1972, pp 183-196.

GOLDNER, William. "The Lowry Model Heritage". *Journal of the American Institute of Planners,* Vol. 37, No. 2, March 1971, pp 100-110.

GREAT BRITAIN, NATIONAL ECONOMIC DEVELOPMENT OFFICE, *Shopping Models,* London: Her Majesty's Stationery Office, 1970.

GRUBB, Edward L. and Harrison L. GRATHWOHL. "Consumer Self-Concept, Symbolism and Market Behavior: A Theoretical Approach". *Journal of Marketing,* Vol. 31, No. 4, Part I, October 1967, pp 22-27.

GRUEN, Claude and Nina J. GRUEN. *Store Location and Customer Behavior,* Washington: Urban Land Institute, Technical Bulletin 56, October 1966.

GRUEN, Victor and Larry SMITH. *Shopping Towns: U.S.A.,* New York: Reinhold, 1960.

HAINES, George H., Jr., Leonard S. SIMON and Marcus ALEXIS. "Maximum Likelihood Estimation of Central-City Food Trading Areas". *Journal of Marketing Research,* Vol. 9, No. 2, May 1972, pp 154-159.

HAYES, Martyn Cordey. *Retail Location Models,* London: Centre for Environmental Studies, C.E.S. Working Paper 16, October 1968.

HAYES, Martyn Cordey and Alan G. WILSON. *Spatial Interaction,* London: Centre for Environmental Studies, Working Paper 57, January 1970.

HERMANN, Robert O. and Leland L. BEIK. "Shoppers' Movements Outside Their Local Trade Area". *Journal of Marketing,* Vol. 32, No. 4, October 1968, pp 45-51.

HORWOOD, Edgar M. "Public Policy and the Outlying Shopping Centre". *Journal of the American Institute of Planners,* Vol. 24, No. 4, Fall 1958, pp 215-222.

HOUSING AND LOCAL GOVERNMENT, Ministry of. *A Method of Estimating Retail Floorspace Requirements in Small and Medium Sized Towns Outside the Conurbations,* London: Her Majesty's Stationery Office, February 1967.

HOWARD, John A. and Jagdish N. SHETH. *A Theory of Buyer Behavior,* New York: John Wiley & Sons, 1969.

HOYT, Homer. *The Dollars and Cents of Shopping Centres*, Washington, D.C.: Urban Land Institute, 1972.

HUFF, David L. "Ecological Characteristics of Consumer Behavior". *Papers and Proceedings of the Regional Science Association*, Vol. 7, 1961, pp 19-28.

HUFF, David L. "A Note on the Limitations of the Intra-Urban Gravity Model". *Land Economics*, Vol. 38, 1962, pp 64-66.

HUFF, David L. "A Probabilistic Analysis of Shopping Centre Trade Areas". *Land Economics*, Vol. 39, No. 1, February 1963, pp 81-90.

HUFF, David L. "Defining and Estimating a Trading Area". *Journal of Marketing*, Vol. 28, No. 3, July 1964, pp 34-38.

HUFF, David L. "A Programmed Solution for Approximating an Optimum Retail Location". *Land Economics*, Vol. 42, No. 3, August 1966, pp 293-303.

HUFF, David L. and Larry BLUE. *A Programmed Solution to Estimating Retail Sales Potentials*, Lawrence, Kansas: Centre for Regional Studies, The University of Kansas, 1964.

JORDEN, G. W. *The Retail Gravity Model: An Examination and Application*, Toronto: Department of Urban and Regional Planning, University of Toronto, 1971 (Unpublished).

KANE, Bernard J., Jr. *A Systematic Guide to Supermarket Location Analysis*, New York: Fairchild, 1966.

KASSARJIAN, Harold H. and Thomas S. ROBERTSON. *Perspectives in Consumer Behavior*, Glenview: Scott, Foresman and Co., 1968.

KELLY, Eugene J. *Shopping Centres - Locating Controlled Regional Centres*, New York: ENO Foundation for Highway Traffic Control, 1956.

KENDRICK, J. G. "Retailing in Canada". *The Canadian Marketer*, Winter 1969-70, pp 11-15.

KERNAN, Jerome B. "Choice Criteria, Decision Behavior, and Personality". *Journal of Marketing Research*, Vol. 5, No. 2, May 1968, pp 155-164.

KERNAN, Jerome B. and Montrose S. SOMMERS. *Perspectives in Marketing Theory*, New York: Meredith, 1968.

KOLLAT, David T., James F. ENGEL and Roger D. BLACKWELL. "Current Problems in Consumer Behavior Research". *Journal of Marketing Research*, Vol. 7, No. 3, August 1970, pp 327-332.

KOTLER, Philip. "Behavioral Models for Analyzing Buyers". *Journal of Marketing*, Vol. 29, No. 4, October 1965, pp 37-45.

KOTLER, Philip. *Marketing Decision Making: A Model Building Approach*, New York: Holt, Rinehart and Winston, 1971.

KUNKEL, John H. and Leonard L. BERRY. "A Behavioral Conception of Retail Image". *Journal of Marketing,* Vol. 32, No. 4, October 1968, pp 21-27.

LAKSHMANAN, T. R. *A Theoretical and Empirical Analysis of Intraurban Retail Location,* Ann Arbor: University Microfilms, Ph. D. Dissertation, Ohio State University, 1965.

LAKSHMANAN, T. R. and Walter G. HANSEN. "A Retail Market Potential Model". *Journal of the American Institute of Planners,* Vol. 31, No. 2, May 1965, pp 134-143.

LAZER, W. and R. G. WYCKHAM. "Perceptual Segmentation of Department Store Markets". *Journal of Retailing,* Vol. 45, No. 2, Summer 1969, pp 3-14.

LEWIS, J. Parry and L. TRAILL. "The Assessment of Shopping Potential and the Demand for Shops". *Town Planning Review,* Vol. 38, No. 4, January 1968, pp 317-326.

LIPSTEIN, Benjamin. "A Mathematical Model of Consumer Behavior". *Journal of Marketing Research,* Vol. 2, No. 3, August 1965, pp 259-265.

LITTLE, Derek. "The Shopping Center Bugaboo". *Municipal World,* June 1972, pp 143,163 ff.

LUCE, R. Duncan. *Individual Choice Behavior,* New York: John Wiley & Sons, 1959.

LYNCH, Kevin. *The Image of the City,* Cambridge: M.I.T. Press, 1960.

MacKAY, David B. "A Microanalytic Approach to Store Location Analysis". *Journal of Marketing Research,* Vol. 9, No. 2, May 1972, pp 134-140.

MacKAY, David B. "Measuring Shopping Patterns". *Geographical Analysis,* Vol. V, No. 4, October 1973, pp 329-337.

MASON, Joseph B. and Charles T. MOORE. "An Empirical Reappraisal of Behavioristic Assumptions in Trading Area Studies". *Journal of Marketing,* Vol. 46, No. 4, Winter 1970-71, pp 31-37.

MATSUSAKI, Hirofumi. "What About the Shopping Movements of Quebec Consumer". *Marketing Involvement in Society and the Economy,* Cincinnati: 1969 Fall Conference Proceedings, American Marketing Association, Series No. 30, Cincinnati, Ohio: American Marketing Association, 1969, pp 194-199.

McCABE, Robert W. *Urban Planning for Retail Facilities in British New Towns,* M. Sc. (Pl.) Thesis, University of Toronto, Department of Urban and Regional Planning, 1965.

McCABE, Robert W. *An Exploration of Programming for a Retail Model,* Toronto: Department of Urban and Regional Planning, University of Toronto, 1968 (Unpublished).

McCABE, Robert W. *Shopping Centre Decisions: Evaluation Guides,* Toronto, Province of Ontario, Ministry of Treasury, Economics, and Intergovernmental Affairs, 1971.

McCABE, Robert W. *Shopping Centres in Ontario.* Toronto: Paper given at Northeastern Ontario Planning Conference, October 1972. (Mimeograph).

McCRACKEN, D. D. *A Guide to Fortran IV Programming,* New York: John Wiley & Sons, 1965.

McNAIR, Malcolm P. *Operating Results of Department and Specialty Stores,* Cambridge, Mass.: Harvard University Graduate School of Business Administration, Business Research Bulletins, 1969.

MONTGOMERY, David B. and Glen L. URBAN. *Management Science in Marketing,* Englewood Cliffs: Prentice-Hall, 1969.

MOORE, Charles T. and Joseph B. MASON. "A Research Note on Major Retail Center Patronage". *Journal of Marketing,* Vol. 33, No. 3, July 1969, pp 57-61.

MOYER, M. S. and G. SNYDER. *Trends in Canadian Marketing,* Ottawa: Dominion Bureau of Statistics. 1961 Census Monograph Programme, 1967.

MURRAY, W. and M. B. KENNEDY. "Notts/Derbys: A Shopping Model Primer". *Journal of the Town Planning Institute,* Vol. 57, No. 5, May 1971, pp 211-215.

NATIONAL ECONOMIC DEVELOPMENT OFFICE. *Urban Models in Shopping Studies,* London: National Economic Development Office, August 1970.

NELSON, Richard L. *The Selection of Retail Locations,* New York: F. W. Dodge, 1958.

OLSSON, Gunnar and Stephen GALE. "Spatial Theory and Human Behavior". *Papers of the Regional Science Association,* Vol. 21, 1968, pp 229-242.

PLANNING AND TRANSPORT RESEARCH AND COMPUTATION COMPANY LTD. *Shopping Models, Parts I and II,* London: Planning and Transport Research and Computation Company Limited, Seminar Proceedings, October 1968.

RABENDA, C. A. *Sensitivity Analysis in Retail Gravity Modelling,* M. Sc. (Pl.) Thesis, University of Toronto, Department of Urban and Regional Planning, 1973.

RAO, Tanniru. "Mathematical Models of Market Behavior: Past, Present, and Future". *Journal of Retailing,* Vol. 47, No. 3, Fall 1971, pp 37-47.

REILLY, William J. *The Law of Retail Gravitation,* New York: W. J. Reilly Co., 1931.

REYNOLDS, Fred D. and William R. DARDEN. "Intermarket Patronage: A Psychographic Study of Consumer Outshoppers". *Journal of Marketing,* Vol. 36, No. 4, October 1972, pp 50-54.

RHODES, Tim and Roy WHITAKER. "Forecasting Shopping Demand". *Journal of the Town Planning Institute,* Vol. 53, No. 5, May 1967a, pp 188-192.

RHODES, Tim and Roy WHITAKER. "A Further Note on Forecasting Shopping Demand". *Journal of the Town Planning Institute*, Vol. 53, No. 9, November 1967b, pp 415-416.

ROBERTS, Margaret. "Shopping(1)". *Official Architecture and Planning*, Vol. 34, No. 2, May 1971a, pp 383-386.

ROBERTS, Margaret. "Shopping(2)". *Official Architecture and Planning*, Vol. 34, No. 7, July 1971b, pp 539-544.

ROBINSON, Krystyna. *Central Place Theory II: Its Role in Planning with Particular Reference to Retailing*, London: Centre for Environmental Studies, Working Paper 9, July 1968.

ROBINSON, Krystyna. *Data and Retailing*, London: Centre for Environmental Studies, Working Paper 25, January 1969.

ROGERS, A. *An Investigation of Retail Land Use Forecasting Models*, San Francisco: Bay Area Transportation Study, 1965.

SCHNEIDER, M. "Gravity Models and Trip Distribution Theory". *Papers and Proceedings of the Regional Science Association*, 1959.

SCHWARTZ, George. *Development of Marketing Theory*, Cincinnati: South-Western, 1963.

SCOTT, Peter. *Geography and Retailing*, London: Hutchinson University Library, 1970.

SIMMONS, James W. *The Changing Pattern of Retail Location*, Chicago: University of Chicago Press, 1964.

SIMMONS, James W. *Toronto's Changing Retail Complex*, Chicago: University of Chicago Department of Geography Research, Paper No. 104, University of Chicago, 1966.

STEDMAN, Gordon H. "The Rise of Shopping Centres". *Journal of Retailing*, Spring 1955, pp 11-26.

STEPHENSON, P. Ronald. "Identifying Elements of Retail Patronage". *Journal of Marketing*, Vol. 33, No. 3, July 1969, pp 57-61.

STERNLIEB, George. *The Future of the Downtown Department Store*, Cambridge, Mass.: Harvard University Press, 1962.

TAUBER, Edward M. "Why Do People Shop?". *Journal of Marketing*, Vol. 36, No. 4, October 1972, pp 46-49.

THOMPSON, B. "Analysis of Supermarket Shopping Habits in Worcester, Massachusetts". *Journal of Retailing*, Vol. 43, No. 3, Fall 1967, pp 17-29.

THOMPSON, Donald L. "New Concept: Subjective Distance". *Journal of Retailing*, Vol. 39, No. 1, Spring 1963, pp 1-6.

THOMPSON, Donald L. "Future Directions in Retail Area Research". *Economic Geography*, Vol. 42, No. 1, January 1966, pp 1-18.

THOMPSON, Donald L. "Consumer Convenience and Retail Area Structure". *Journal of Marketing Research*, Vol. 4, No. 1, February 1967, pp 37-44.

TIGERT, Douglas J. *The Changing Structure of Retailing in Europe and North America: Challenges and Opportunities*, Toronto: Faculty of Management Studies, University of Toronto, January 1974.

TIGERT, Douglas J. and Donald J. TIGERT. "Longitudinal Analysis of a Supermarket Price War: A New Look at the Price-Quality Relationship". 1971 Proceedings American Marketing Association Fall Conference, Minneapolis, Minn.: American Marketing Association, 1971.

TOWN PLANNING INSTITUTE. *Predicting Shopping Requirements*, Birmingham: Town Planning Institute, West Midlands Branch, August 1967.

TRI-COUNTY REGIONAL PLANNING COMMISSION. *Shopping Centre Effects on Central Business Districts*, Akron, Ohio: Regional Planning Study No. 37, Tri-County Regional Planning Commission (Medina-Summit-Portage), October 1965.

UNITED STATES, DEPARTMENT OF COMMERCE. *Calibrating and Testing a Gravity Model with a Small Computer*, Washington, Department of Commerce, Bureau of Public Roads, 1963.

UNIVERSITY OF MANCHESTER. *Regional Shopping Centres: A Planning Report on North West England, Part I and Part II (A Retail Shopping Model)*, Manchester: Department of Town and Country Planning, University of Manchester, 1964 and 1966.

URBAN LAND INSTITUTE. *The Community Builders Handbook*, Washington, D.C.: Urban Land Institute, 1969.

URBAN LAND INSTITUTE. *The Dollars and Cents of Shopping Centres:* Washington: Urban Land Institute, 1972.

WADE, B. F. *Greater Peterborough Shopping Study: Technical Report*, Reading: Planning Research Applications Group, January 1973.

WHITE, L. A. and J. B. ELLIS. "A System Construct for Evaluating Retail Market Locations". *Journal of Marketing Research*, Vol. 8, No. 1, February 1971, pp 43-46.

WILSON, Alan G. "A Statistical Theory of Spatial Distribution Models". *Transportation Research*, Vol. 1, No. 3, November 1967, pp 253-269.

WILSON, Alan G. "Notes on Some Concepts in Social Physics". *Papers of the Regional Science Association*, Vol. 22, 1969a, pp 159-193.

WILSON, Alan G. "The Use of Entropy Maximizing Models in the Theory of Trip Distribution, Mode Split and Route Split". *Journal of Transport Economics and Policy*, Vol. 3, No. 1, January 1969b, pp 108-126.

WILSON, Alan G. "Entropy". London: Centre for Environmental Studies, Working Paper 26, January 1969c.

WILSON, Alan G. "Inter-regional Commodity Flows: Entropy Maximizing Approaches". *Geographical Analysis*, Vol. 2, No. 3, July 1970a, pp 255-282.

WILSON, Alan G. *Entropy in Urban and Regional Modelling*, London: Pion Press, 1970b.

WILSON, Alan G. *Papers in Urban and Regional Analysis*, London: Pion Press, 1972.

A number of comprehensive bibliographies on shopping centres, downtown development, etc. have been available in the past. Some of these are listed below.

A Basic Bibliography for Downtown Development,
National Retail Merchants Association, n.d.,
100 West 31 Street, New York, New York, 10001,
31 pages.

Selected Bibliography on Shopping Centres,
International Council of Shopping Centres,
342 Madison Avenue, New York, New York, May 1962.
9 pages.

Exchange Bibliography Nos. 12, 16 and 208.
Council of Planning Librarians,
Post Office Box 229, Monticello, Illinois, 61856,
November 1959, 56 pages, August 1960, 26 pages, August 1971, 34 pages.

Selected Annotated Bibliography on Shopping Centres,
The Kroger Co.,
35 East Seventh Street, Cincinnati, Ohio,
January 1957.